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"This is one of the jewels in the Sky-Watcher crown. Its large enough to produce richly detailed, high-contrast, Lunar & Planetary images" **Ade Ashford, www.scopetest.com**

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Sir Patrick Moore CBE FRS (1923-2012)

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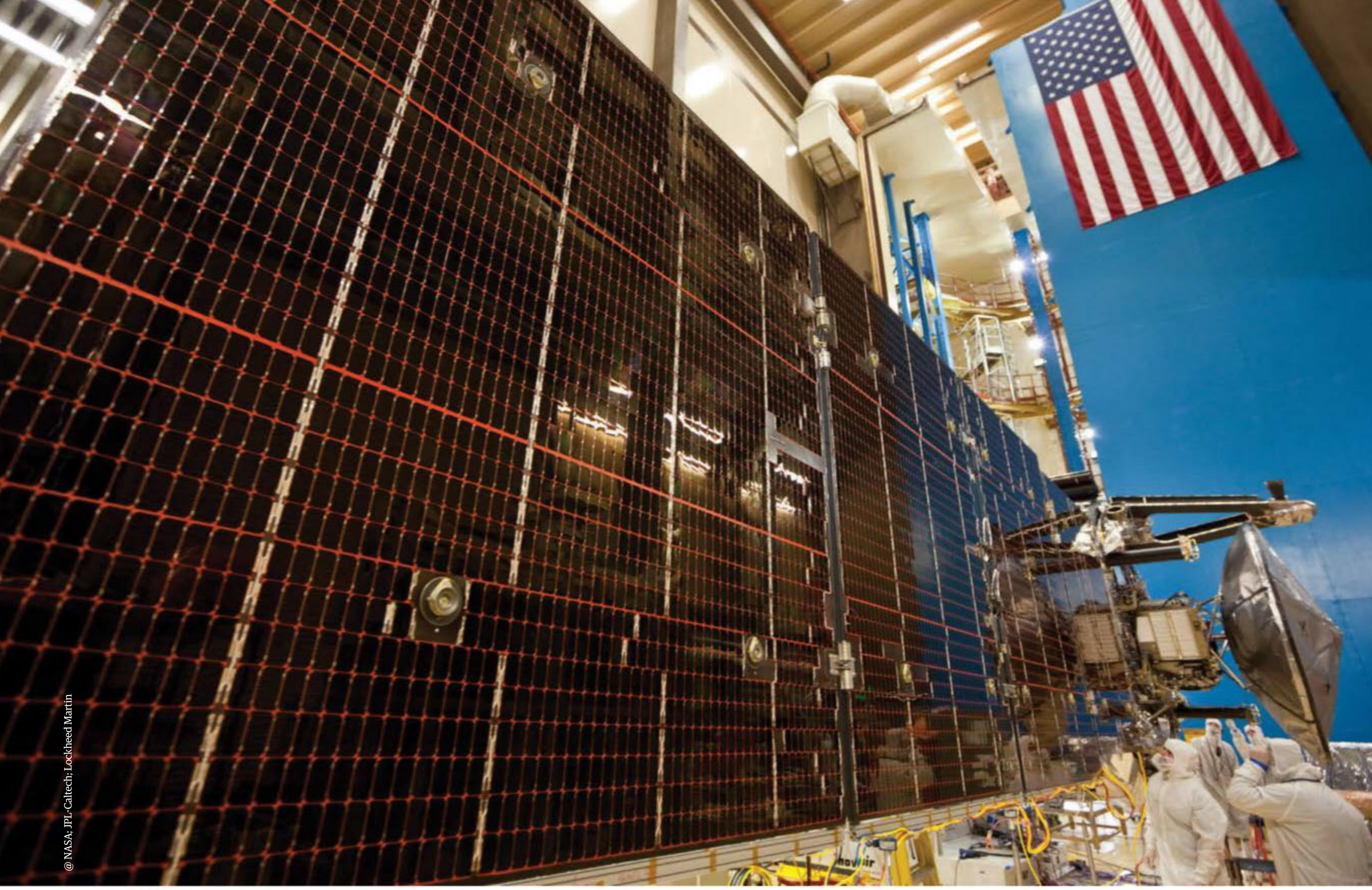

@ NASA; JPL-Caltech; Lockheed Martin

On 4 July, NASA's Juno spacecraft reaches Jupiter

Discover the wonders of the universe

It's a common belief that black holes are literally deep wells in the fabric of space-time, with a gravity so strong they're able to devour stars and planets as well as tightly grip the fastest thing in the universe: light.

While the power that these objects wield is undeniable, you might be surprised to learn that these exotic members of the cosmos are spherical. They're also not as black as we initially thought and – according to Stephen Hawking – some types of radiation are capable of escaping their clutches.

If you've ever wondered what we actually know about black holes, then wonder no more – this issue, we bring you a complete guide that covers everything you need to know about these hefty, exotic objects, which can weigh in at billions of times the mass of the Sun.

Very soon, social media and our television screens will bring us the news that NASA's Juno spacecraft has finally reached gas giant Jupiter. **All About Space** caught up with the mission's principal investigator, Scott Bolton, to find out what we can expect in the coming months, and even years, from the spacecraft.

Before that, it's Asteroid Day on 30 June, which falls on the anniversary of the Tunguska event – the result of what is suspected to be a meteor exploding close to the Stony Tunguska River, Krasnoyarsk Krai, in 1908. Just like the Chelyabinsk impact in 2013, Tunguska is a stark reminder that we could one day be wiped out by a chunk of space rock – that is, if we don't have a plan to protect ourselves. This month we uncover how close we are to having an Earth protection programme, but not before SpaceX's Elon Musk tells us all about his plans to launch for Mars in 2018!

Gemma Lavender
Editor

Contributors

Kulvinder Singh Chadha

This month, Kulvinder tells you everything you need to know about black holes. From one factoid to the next, we promise you'll be amazed.

Giles Sparrow

On 4 July, NASA's Juno spacecraft will finally reach Jupiter. Giles speaks to the mission's PI, who tells us what mysteries the mission could unravel about the gas giant.

Ben Evans

If we could solve all of the puzzles of the universe, we would see it as a very different place. Ben uncovers just how different over on page 38.

Jonny O'Callaghan

It's Asteroid Day on 30 June. Jonny finds out what plans we have in place to protect our home planet from an asteroid impact that's capable of wiping out life on Earth as we know it.

> "Some of the main ideas for Juno came from the leftover questions raised by Galileo"
>
> **Scott Bolton, principal investigator of NASA's Juno spacecraft [page 30]**

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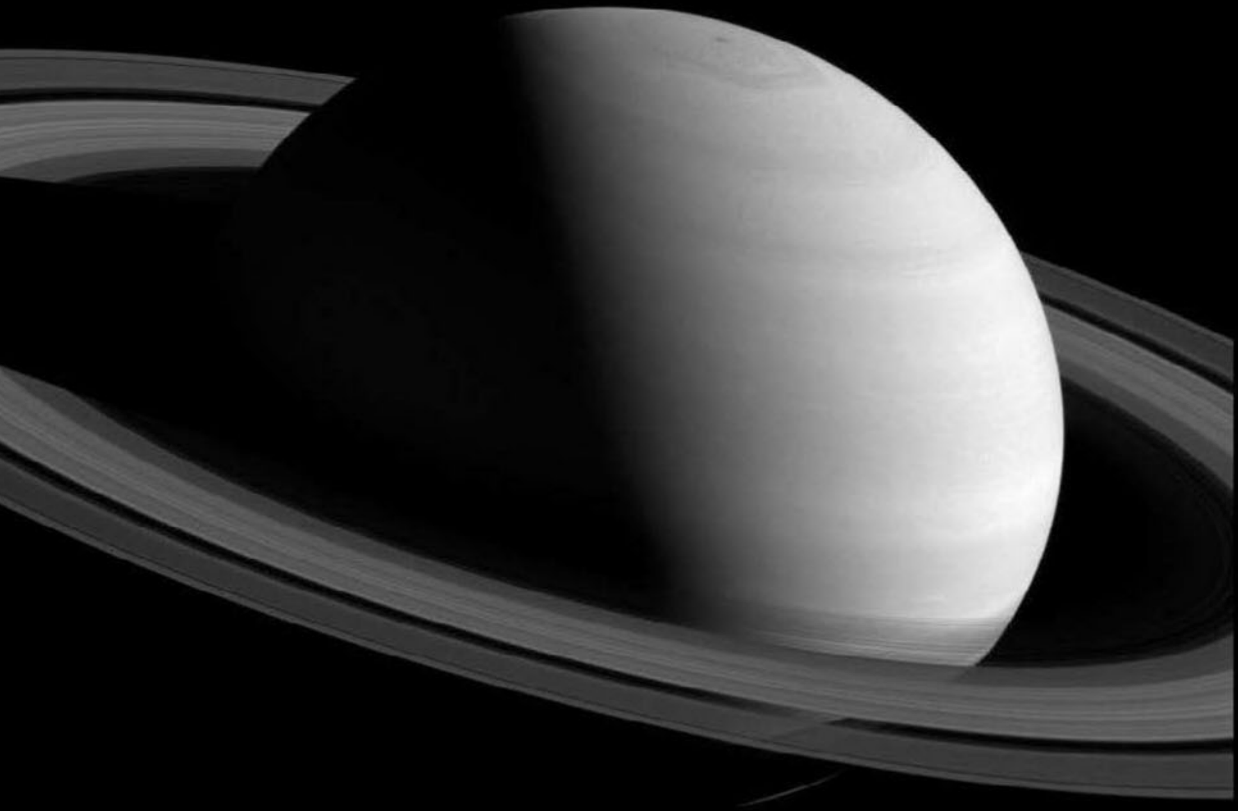
Three-millionth image aboard the International Space Station

The crew of Expedition 47 take a moment out of their busy schedule to pose for what marks a milestone in the history of the International Space Station – the 3 millionth image taken on the Earth-orbit habitat. Such a large volume of snaps also reminds astronauts from the Russian, European and American space agencies that many men and women have photographed our unique planet from space for over 15 years.

Expedition 47 comprises of (front row from left to right) the European Space Agency's Tim Peake, NASA astronaut Timothy Kopra and Roscosmos cosmonaut Yuri Malenchenko, as well as (back row from left to right) Russian cosmonauts Oleg Skripochka and Alexey Ovchinin and NASA astronaut Jeff Williams.

@NASA

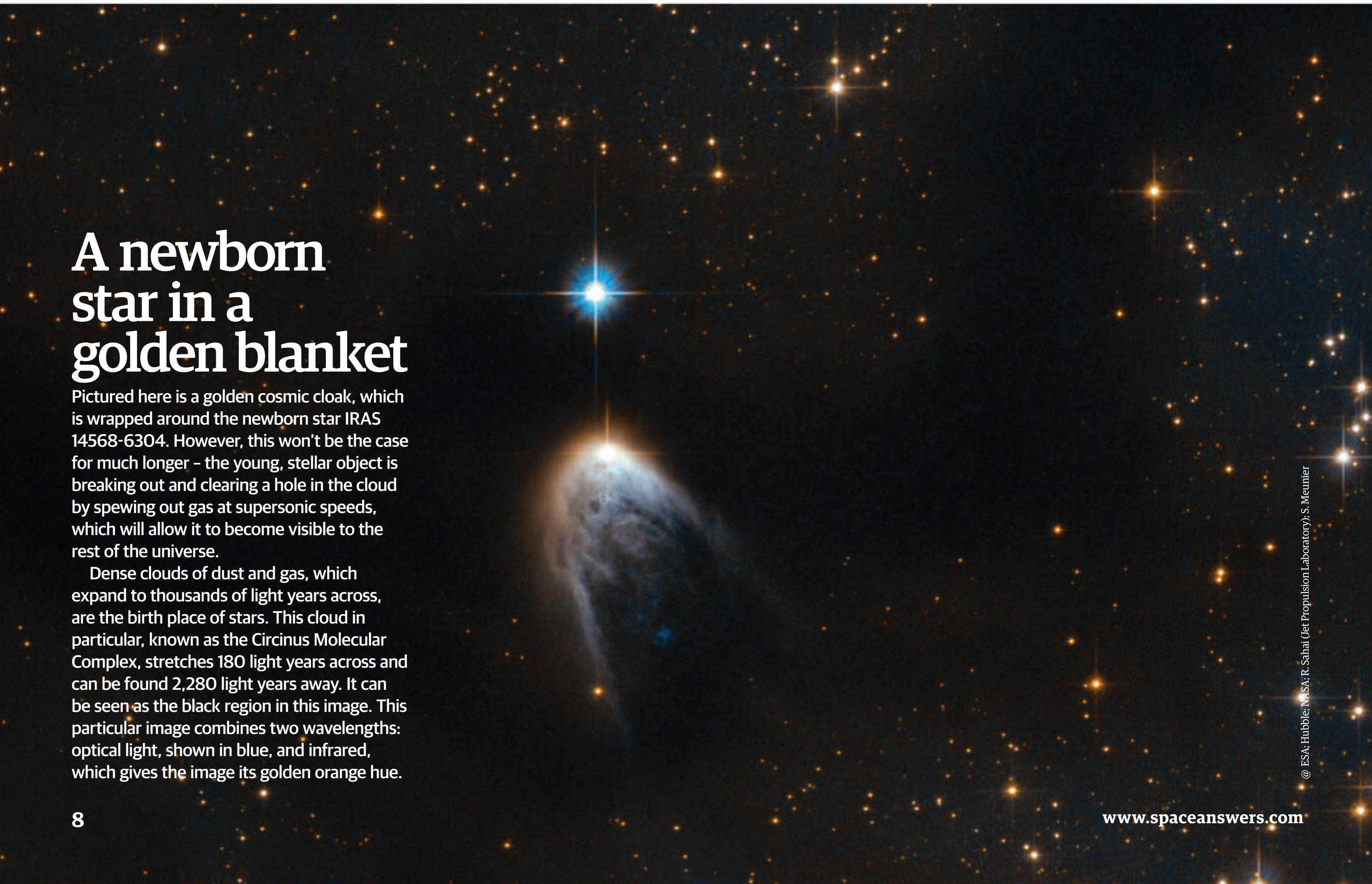


Saturn takes a bow

Ringed giant Saturn appears to stoically look toward the Sun in this striking image returned by the Cassini spacecraft's wide-angle camera. The NASA mission has been studying the Saturnian system for over ten years and has uncovered a large amount of information about the ringed planet and its moons.

In this particular view, Cassini spotted a photo opportunity during February of this year as sunlight played on the gas giant's rings, which are majestically tilted at 16 degrees. The spacecraft obtained the image from a distance of around 2.8 million kilometres (1.7 million miles) away from Saturn.

@ NASA; JPL-Caltech; Space Science Institute

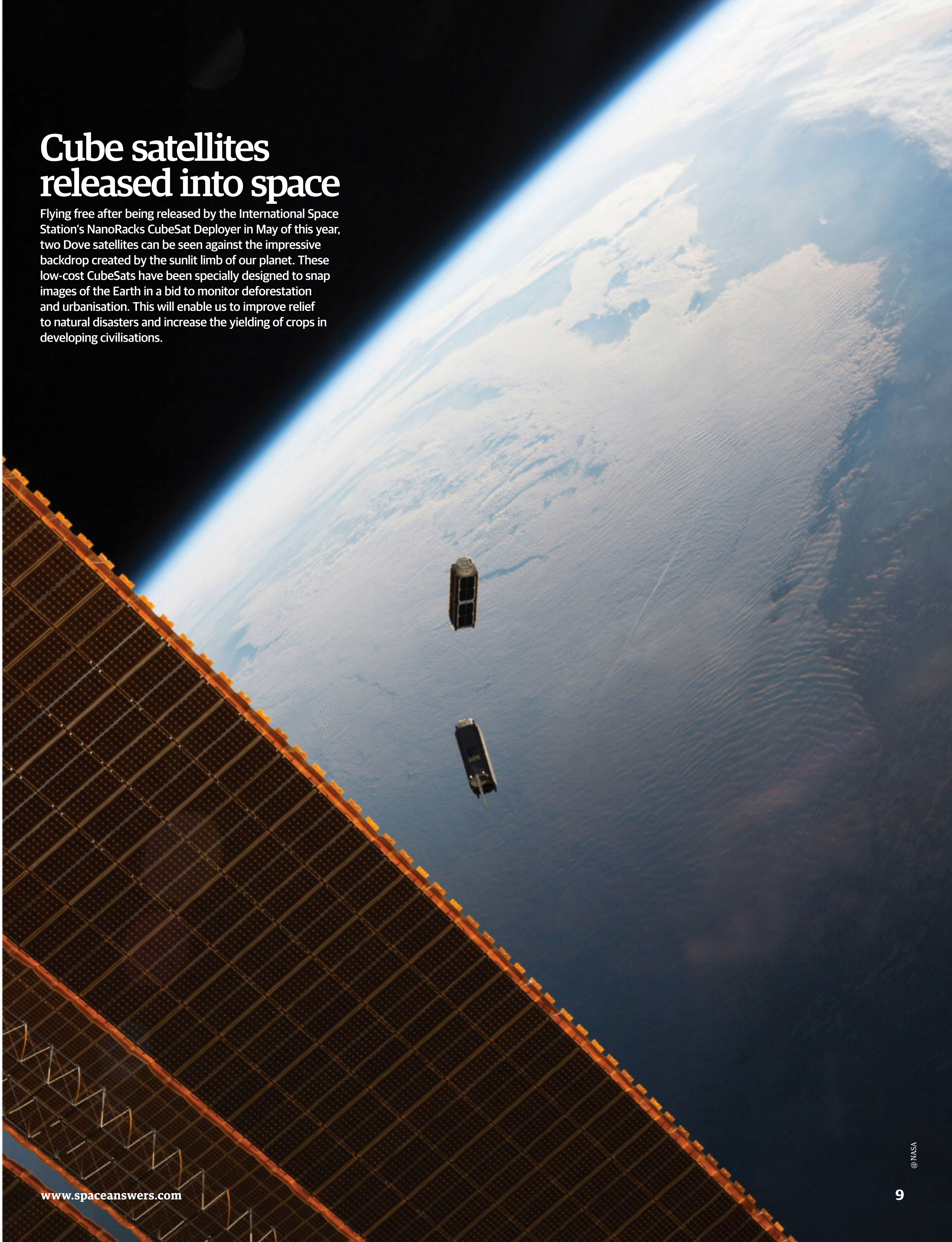


A newborn star in a golden blanket

Pictured here is a golden cosmic cloak, which is wrapped around the newborn star IRAS 14568-6304. However, this won't be the case for much longer – the young, stellar object is breaking out and clearing a hole in the cloud by spewing out gas at supersonic speeds, which will allow it to become visible to the rest of the universe.

Dense clouds of dust and gas, which expand to thousands of light years across, are the birth place of stars. This cloud in particular, known as the Circinus Molecular Complex, stretches 180 light years across and can be found 2,280 light years away. It can be seen as the black region in this image. This particular image combines two wavelengths: optical light, shown in blue, and infrared, which gives the image its golden orange hue.

@ ESA; Hubble; NASA; R. Sahai (Jet Propulsion Laboratory); S. Meunier



Cube satellites released into space

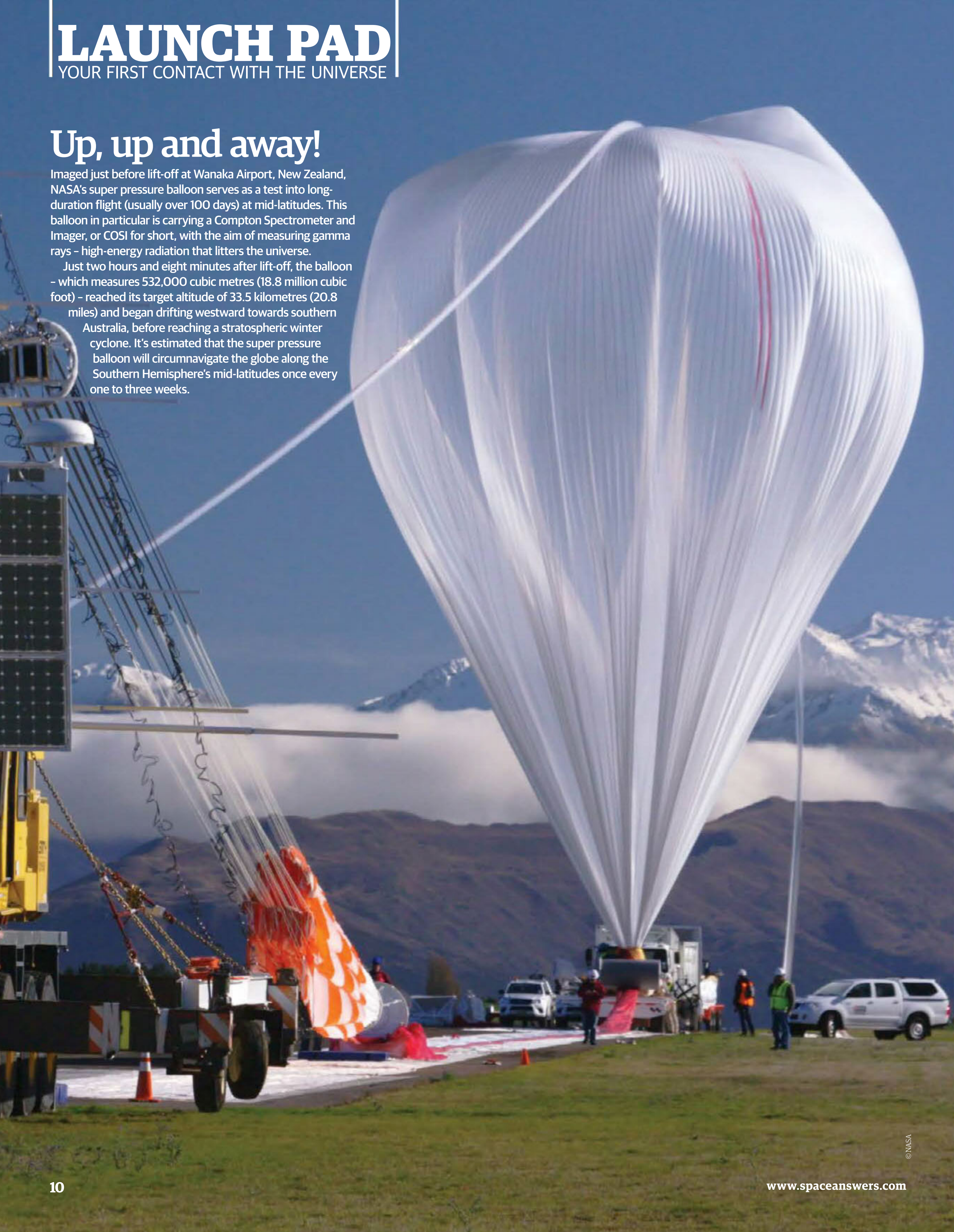
Flying free after being released by the International Space Station's NanoRacks CubeSat Deployer in May of this year, two Dove satellites can be seen against the impressive backdrop created by the sunlit limb of our planet. These low-cost CubeSats have been specially designed to snap images of the Earth in a bid to monitor deforestation and urbanisation. This will enable us to improve relief to natural disasters and increase the yielding of crops in developing civilisations.

@NASA

Up, up and away!

Imaged just before lift-off at Wanaka Airport, New Zealand, NASA's super pressure balloon serves as a test into long-duration flight (usually over 100 days) at mid-latitudes. This balloon in particular is carrying a Compton Spectrometer and Imager, or COSI for short, with the aim of measuring gamma rays – high-energy radiation that litters the universe.

Just two hours and eight minutes after lift-off, the balloon – which measures 532,000 cubic metres (18.8 million cubic foot) – reached its target altitude of 33.5 kilometres (20.8 miles) and began drifting westward towards southern Australia, before reaching a stratospheric winter cyclone. It's estimated that the super pressure balloon will circumnavigate the globe along the Southern Hemisphere's mid-latitudes once every one to three weeks.



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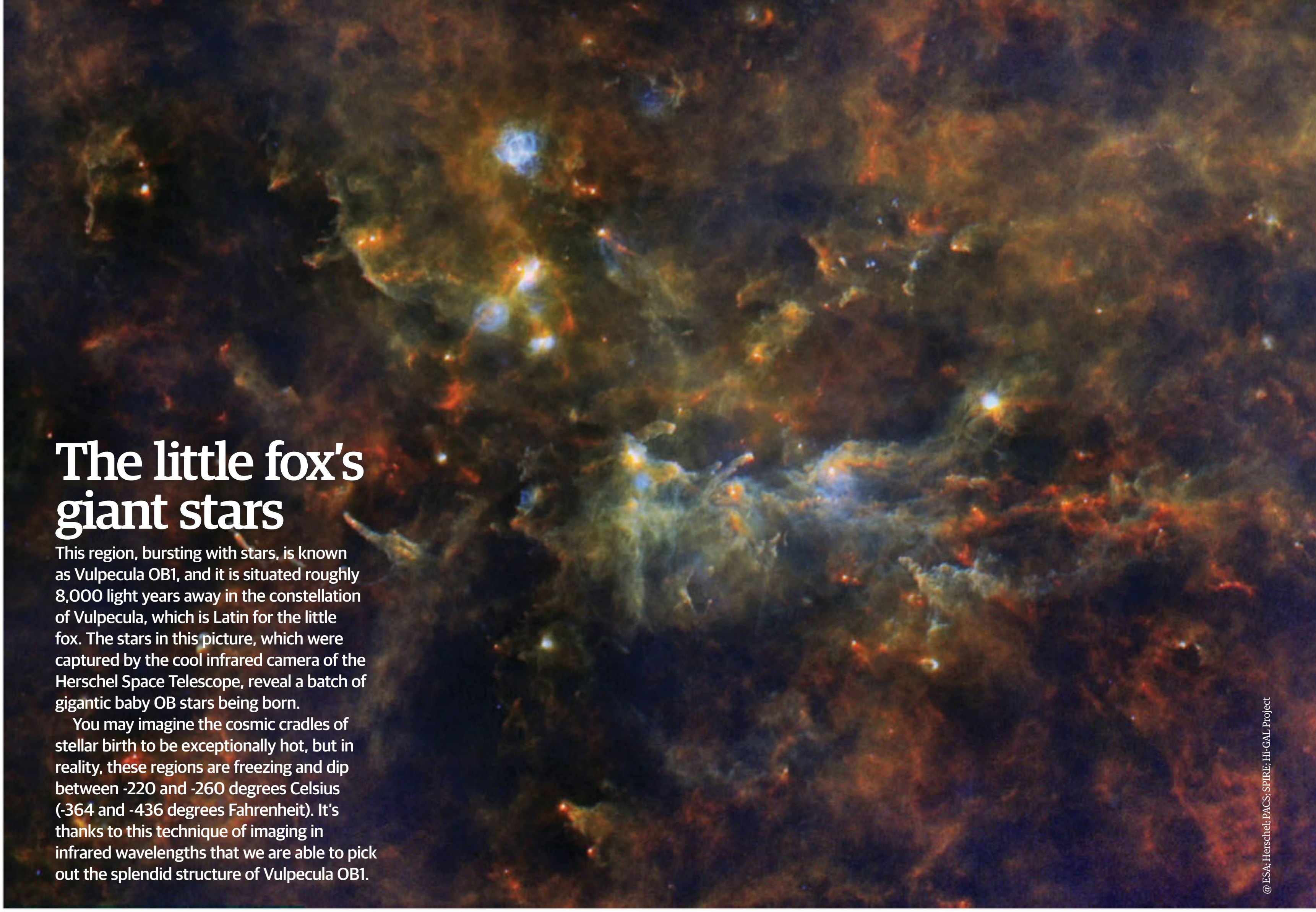

The little fox's giant stars

This region, bursting with stars, is known as Vulpecula OB1, and it is situated roughly 8,000 light years away in the constellation of Vulpecula, which is Latin for the little fox. The stars in this picture, which were captured by the cool infrared camera of the Herschel Space Telescope, reveal a batch of gigantic baby OB stars being born.

You may imagine the cosmic cradles of stellar birth to be exceptionally hot, but in reality, these regions are freezing and dip between -220 and -260 degrees Celsius (-364 and -436 degrees Fahrenheit). It's thanks to this technique of imaging in infrared wavelengths that we are able to pick out the splendid structure of Vulpecula OB1.

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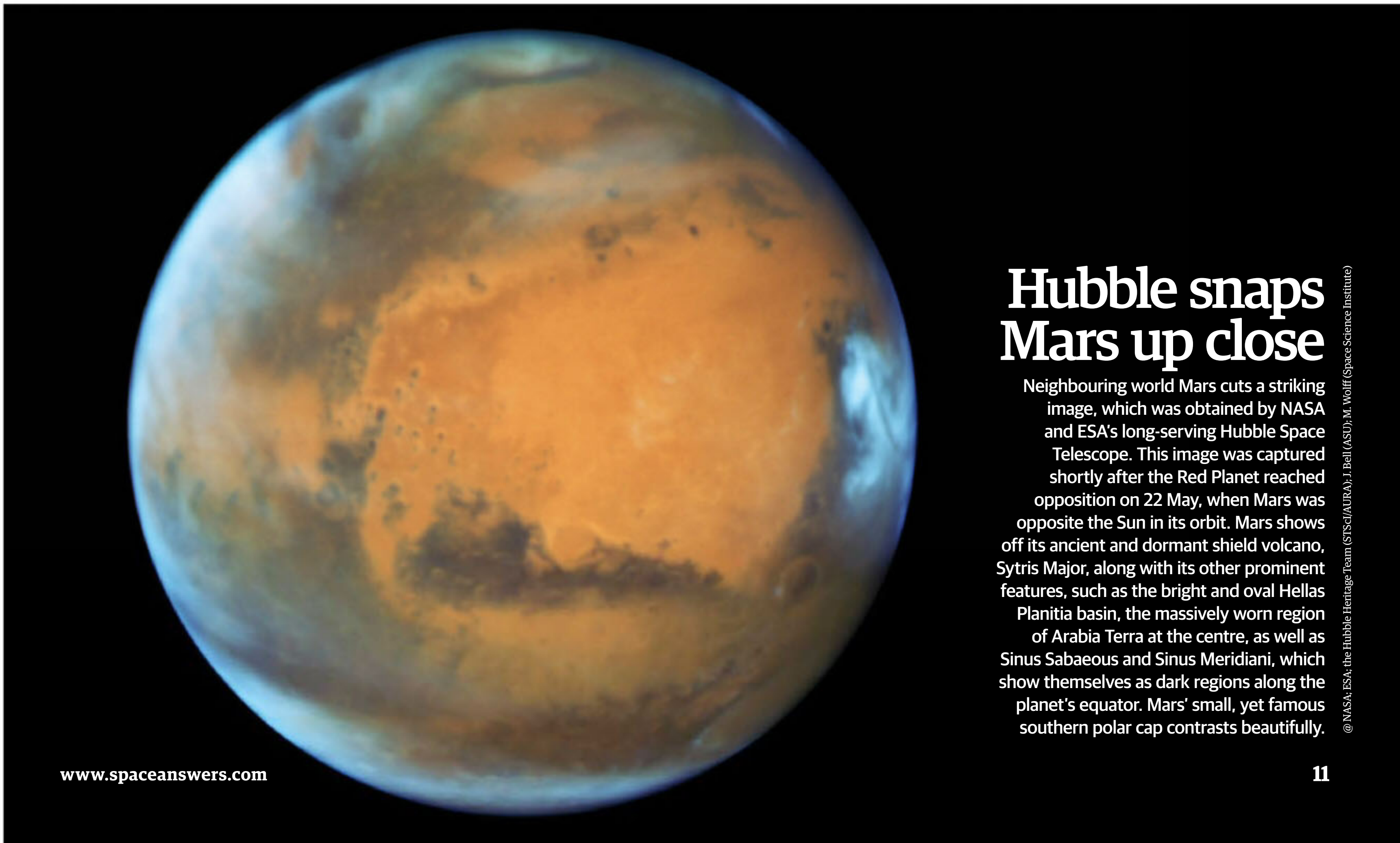

Hubble snaps Mars up close

Neighbouring world Mars cuts a striking image, which was obtained by NASA and ESA's long-serving Hubble Space Telescope. This image was captured shortly after the Red Planet reached opposition on 22 May, when Mars was opposite the Sun in its orbit. Mars shows off its ancient and dormant shield volcano, Sytris Major, along with its other prominent features, such as the bright and oval Hellas Planitia basin, the massively worn region of Arabia Terra at the centre, as well as Sinus Sabaeous and Sinus Meridiani, which show themselves as dark regions along the planet's equator. Mars' small, yet famous southern polar cap contrasts beautifully.

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New Horizons reveals information on first object beyond Pluto

Through the LORRI lens of the NASA spacecraft, we're now able to investigate another body in the Kuiper Belt

NASA's long-serving New Horizons spacecraft has recently collected data on an object within our Solar System that lies further out than dwarf planet Pluto – a celestial remnant that holds the potential to unlock many of the mysteries surrounding the earliest days of the Solar System.

The object, named 1994 JR1, has actually been identified twice – once in November 2015 when astronomers observed a 150-kilometre (90-mile) wide Kuiper Belt Object (KBO) orbiting more than 5 billion kilometres (3 billion miles) from the Sun and a second time between 7 and 8 April 2016. This second observation, which again used New Horizons' Long Range Reconnaissance Imager (LORRI), picked out the KBO from a distance of about 111 million kilometres (69 million miles).

The images captured also beat New Horizons' own record for the closest-ever views of this KBO from November 2015, when the spacecraft detected JR1 from a still mightily impressive 280 million kilometres (170 million miles) away.

The data collected has now enabled astronomers to extract some enlightening facts about this far-flung object. "Combining the November 2015 and April 2016 observations allows us to pinpoint the location of JR1 to within 1,000 kilometres (620 miles), far better than any small KBO," says Simon Porter, a New Horizons science team member from the Southwest Research Institute (SwRI) in Boulder, Colorado. He adds that the more accurate orbit allows the science team to dispel an existing theory that JR1 is a quasi-satellite of Pluto.

The 2016 observations have also revealed more details regarding JR1's rotation period, noting the alterations in light reflected from JR1's surface indicate that it rotates once every 5.4 hours (or a single JR1 day). "That's relatively fast for a KBO," comments science team member John Spencer, also from SwRI. "This is all part of the excitement of exploring new places and seeing things never seen before."

These observations have provided New Horizons and its team with an exciting chance to practise studying objects within the Kuiper Belt, as the spacecraft prepares to conduct a flyby of another KBO, 2014 MU69, on New Year's Day in 2019.

New Horizons has previously been beaming back astounding new photos of Pluto and its five moons, and astronomers are hoping for just as much clarity and detail when it reaches the Kuiper Belt.

LISA Pathfinder begins tracking the path of gravitational waves

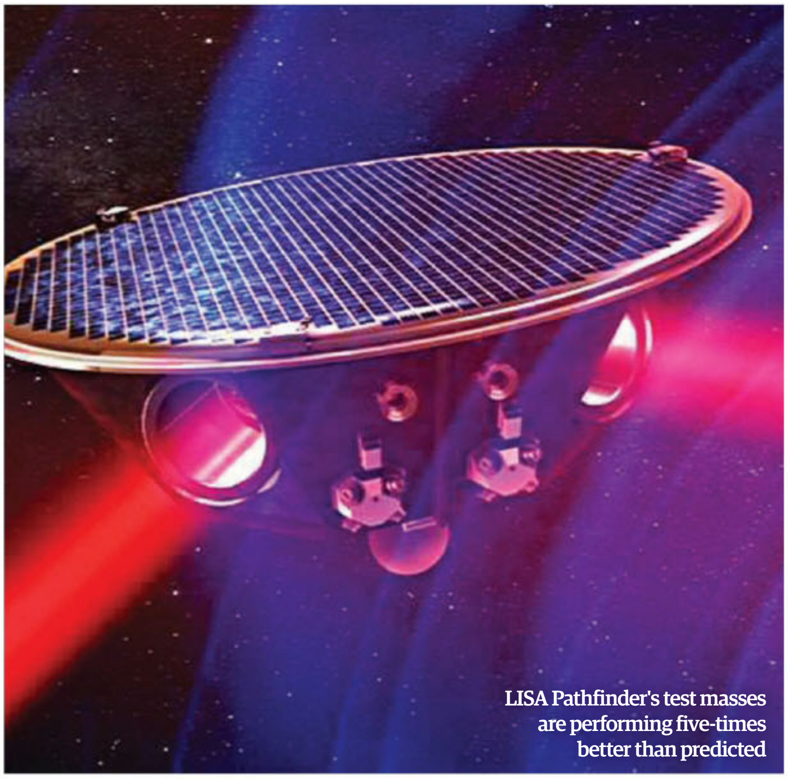
The ESA space observatory is now listening to the sound of the cosmos itself

Following a successful launch back in December 2015, the Laser Interferometer Space Antenna (LISA) Pathfinder spacecraft has been locked in gravitational stasis from March this year and has now been operating beyond expectation for two months.

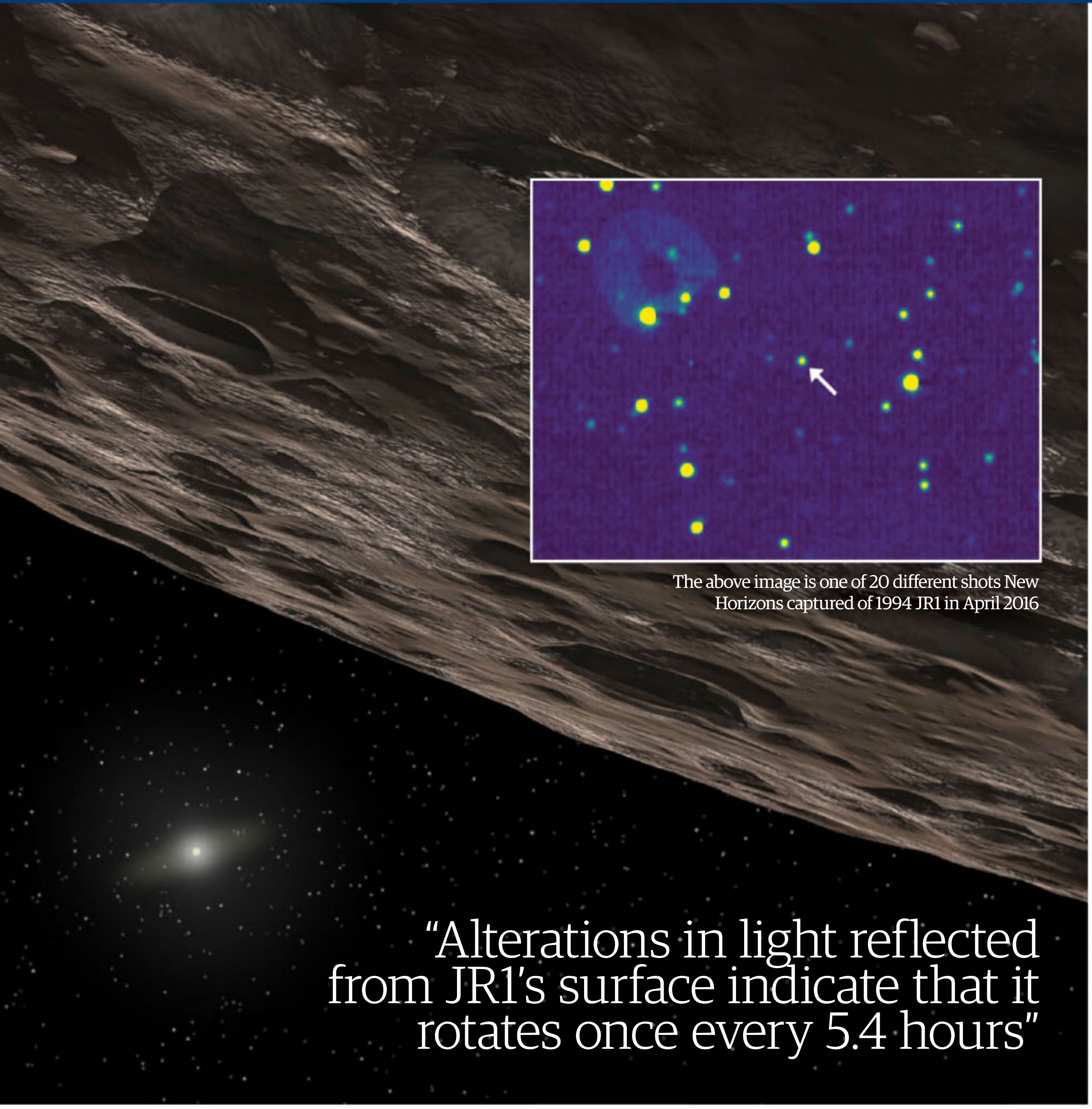
The ESA's space observatory – which is now anchored some 1.5 million kilometres (930,000 miles) from the Earth at L1 – can now begin one of its most exciting goals: tracking the path and behaviour of gravitational waves, a curvature in space-time first observed in February this year.

"With LISA Pathfinder we have created the quietest place known to humankind. Its performance is spectacular and exceeds all of our expectations by far," says Professor Karsten Danzmann, director at the Max Planck Institute for Gravitational Physics, director of the Institute for Gravitational Physics at Leibniz Universität Hannover and co-principal investigator of the LISA Technology Package. "Only by reducing and eliminating all other sources of disturbance could we observe the most perfect free fall ever created," he adds. "And this has shown us that we can build LISA, a space-based gravitational-wave observatory."

The LISA Pathfinder hasn't been operating like a traditional space telescope either – instead, it is using a pair of gold-platinum alloy cubes that float in free fall beneath the craft. Free of other forces, these cubes act like microphones, picking up the echo of gravitational waves passing by the Earth



LISA Pathfinder's test masses are performing five-times better than predicted



The above image is one of 20 different shots New Horizons captured of 1994 JR1 in April 2016

> "Alterations in light reflected from JR1's surface indicate that it rotates once every 5.4 hours"

Facebook's Mark Zuckerberg chats with the ISS

The Facebook CEO grills three of the ISS astronauts on many subjects, including new technology that could take us to Mars

Three astronauts on board the ISS discuss all things space with Facebook CEO Mark Zuckerberg via a live video chat

It's not every day you get to have a live video chat with a trio of multinational astronauts, but that's exactly what we got earlier in the month with a milestone exchange between Facebook CEO Mark Zuckerberg and Tim Kopra, Jeff Williams and Britain's very own Tim Peake.

The 20-minute chat, which was broadcast live on NASA's official Facebook page, gave viewers the opportunity to submit questions to the western crew of the International Space Station (ISS) and the answers helped to peel back a little of the mystique behind the inner machinations of such a landmark craft.

Zuckerberg was also keen to learn what new technology aboard the station is taking humanity one step closer to Mars-focused missions. "The ISS programme is a big achievement in terms of the path to future exploration," comments NASA astronaut Jeff Williams. "Just building, running and maintaining it logistically, learning how to operate it day to day, in the long term, and for years to come, well that's going to support future exploration no matter where we go." Williams also went on to discuss the recently unfolded BEAM module, which NASA hopes will help propel larger components into space with fewer launches - a vital component for future missions to the Red Planet.

Space News in Brief

New research promises life on icy moon, Europa

A new report suggests Europa, the sixth-closest moon to gas giant Jupiter, could potentially possess the conditions needed to support life. The crux of the study bases this on the belief that the Galilean moon has an ocean of liquid water lying beneath its icy crust - however, this report states this would only be possible is there is little or no volcanic activity.

Twin stars give clues on the formation of hot Jupiters

After more than two decades of study, astronomers have unlocked new clues to the birth of gas giants in unusual short-period orbits. A new study has suggested that systems with two stars could have played a role in their formation, with a three out of four chance of these particular 'hot Jupiters' being found in double star systems.

Astronomers get closer to working out our galaxy's mass

Astrophysicist Gwendolyn Eadie and her academic supervisor William Harris, a professor of physics and astronomy at McMaster University, are one step closer to finally being able to determine the mass of the Milky Way. Her method measures large star clusters (known as globular clusters or GCs) orbiting our Solar System and the results could finally bring us an answer.

Supermassive black holes are warming the Milky Way

For billions of years, many galaxies in the universe have been slowly heating up, making them potentially less effective environments for forming new stars. Astronomers at the Sloan Digital Sky Survey have now suggested that a new type of galaxy, which is known as a 'red geyser', could be the culprit for this, thanks to its slew of supermassive black holes.

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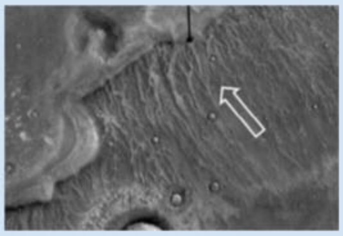


The effects of the older tsunami, with channels carved into its debris by tsunami water, can be seen returning to an ocean elevation

Giant tsunamis battered the coastlines of a younger Mars

Oceanic barriers could have been buried beneath the surface of an ancient Red Planet

According to new NASA-funded research, the ancient oceans that covered Mars produced massive tsunamis that battered the coastlines and, as a result, helped to shape the planet's coastal layout.

For years, scientists have argued as to when Mars' oceans existed, with a lack of defined coastlines on the Red Planet's surface leading many to believe these liquid bodies only existed in early Martian history. However, according to J Alexis P Rodriguez, a senior research scientist at the Planetary Science Institute in Arizona, these coastal networks were in fact buried by two separate tsunami events.

"We were surprised to find that the older and younger tsunami deposits look so different," says Rodriguez. "The older tsunami deposited enormous volumes of debris, and evidence for the water hurtling back into the ocean is represented in widespread 'backwash.'" The coastlines themselves would have receded due to a lack of river systems to refill them before these events buried them. Interestingly, these events also give us an insight into the ecological evolution of the planet - the younger deposits may contain ice from the earliest Martian ocean.

"We think that after the shoreline receded to a lower elevation, the younger tsunami occurred, with enormous waves freezing as it washed over the frozen Martian landscape," adds Rodriguez.

Data suggests that hospitable zone planets smaller than Earth may be better at shedding hot atmospheres

Earth-like exoplanets 'most likely' too hot for life

New research suggests the 'habitable zone' planets might not be so habitable after all

Over the years, NASA and its Kepler spacecraft have discovered thousands of distant planets that exist within a 'habitable zone' (near enough to a dwarf star to maintain liquid water), but a new report reveals many of these Earth-like worlds could be too hot to be hospitable.

"It was previously assumed that planets with masses similar to Earth would be habitable simply because they were in the habitable zone," says James Owen of the Institute for Advanced Study, Princeton, New Jersey. "However, when you consider how these planets evolve over billions of years, this assumption turns out to not be true."

Owen and his team believe these distant worlds - most of which are orbiting stars dimmer than our Sun called red dwarfs, or M dwarfs - were born with hydrogen-helium atmospheres that constitute about one per cent of each planet's total mass. This thick atmosphere would trap heat, making the chance of supporting liquid water - and life - much less likely.

It was previously thought that Earth-like planets orbiting red dwarfs were considerably more active, driving off much of this heat and radiation to create a more hospitable environment. But the study suggests planets of a similar size to Earth are more likely to retain their atmospheres and this dangerous heat.

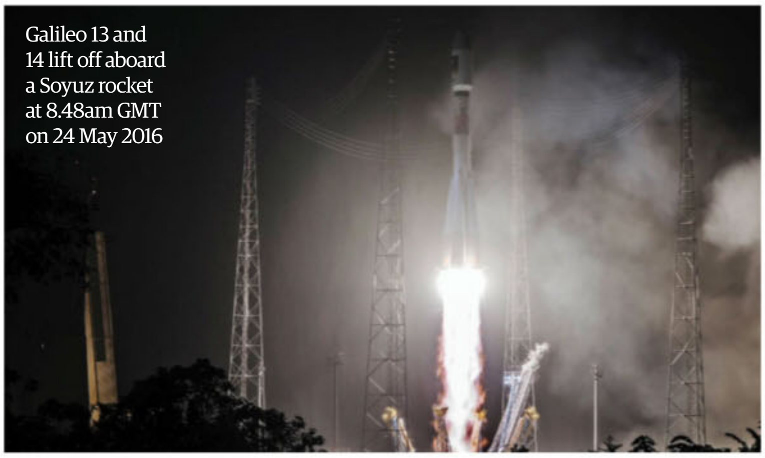
"There are hints from exoplanet discoveries that puny planets may be even more common around red dwarfs than Earth-mass or larger ones - there may indeed be a bonanza of potentially habitable planets whirling around these red stars," adds Subhanjoy Mohanty of Imperial College London.

ESA send 14 Earth-observation satellites to space

The Galileo network of satellites is now larger than ever

Following two successful launches last month from French Guiana, the European Space Agency's ever-growing Galileo satellite programme has now increased to an impressive 14 different craft. The double launch - which propelled Galileo 13 and Galileo 14 into orbit around the Earth - went off without a hitch, with both satellites blasting off atop a Soyuz rocket operated by French multinational launch specialists, Arianespace.

"Today's textbook launch has added two more satellites to what has become Europe's largest satellite constellation," comments Jan Woerner, director general of ESA. "It was made possible by the fact that the European industry's manufacturing and testing of Galileo satellites has achieved a steady tempo."



Galileo 13 and 14 lift off aboard a Soyuz rocket at 8.48am GMT on 24 May 2016

The twin satellites were sent off into orbit, reaching an altitude of around 23,500 kilometres (14,600 miles) just under four hours after taking off. In the days that followed, ESA and Arianespace staff conducted a sequence of small adjustments to get the two satellites into their final operational orbit. According to ESA, there will then be a testing phase so that Galileo 13 and 14 can join the working constellation later this year.

"Today's launch brings Europe's Galileo constellation halfway to completion, in terms of numbers," says Paul Verhoef, ESA's director of the Galileo Programme and Navigation-related Activities. "It is also significant as it is Galileo's last flight by Soyuz this year," he adds, as the first launch using a customised Ariane 5 - which will carry four rather than two satellites per launch - is set to occur this autumn.

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IS THIS WHAT A BLACK HOLE LOOKS LIKE?

They're perplexing and mystifying, yet we know more about black holes than you might realise

Written by Kulvinder Singh Chadha

© Mark Garlick

They are spherical

Black holes are often depicted graphically as funnels in a mesh-like surface, or similarly, as whirlpools. This is often the most straightforward way to show their behaviour. Such depictions, however, shouldn't be taken too literally. Black holes are spherical - at least the event horizon region surrounding the 'singularity' is, and are not actually 'holes' (as far as we know) in the fabric of our universe. The term 'black hole' is thus a colloquialism.

They have an almost supernatural hold over our imaginations: dark, cosmic entities that seemingly rebel against nature. Black holes have mesmerised us for 50 years. Nothing can ever come out of one, and anything that falls in is lost forever. They are the ultimate beasts of the cosmos, feasting upon unsuspecting matter and radiation. However, we now know that black holes are more nuanced and complex than that. They surprise us at every turn with their perplexing properties and baffling behaviour. Black holes aren't funnels or vortices, nor are they even entirely black.

In 1783, English clergyman John Michell proposed the idea of a star whose escape velocity (the speed required to escape a body's gravitational pull) was so high that it went beyond the speed of light. The star's light would be trapped by its own gravity, rendering it invisible. Michell theorised that such 'dark stars' could be found in binary star systems where one star appeared to orbit an invisible partner. Pierre-Simon Laplace, a French mathematician, independently proposed something similar in 1796. Michell and Laplace's idea didn't gain much traction because no one at the time could fathom how light could be affected by gravity.

It was in the 20th century that the idea of 'dark stars' re-emerged. Albert Einstein completely rethought the notion of gravity with his general theory of relativity, published in 1915. Instead of being an attractive force, Einstein imagined gravity as a 'warp' or 'dip' in space-time caused by a mass. Imagine a large, steel ball bearing in the middle of a stretched Lycra sheet. The ball bearing would warp the sheet (the warp being gravity), with the effect being more extreme closer to the mass. If something smaller like a marble found itself within this warp, it would be drawn ever closer towards the ball bearing. Now imagine this happening to the space-time fabric around stars and planets – but in three dimensions.

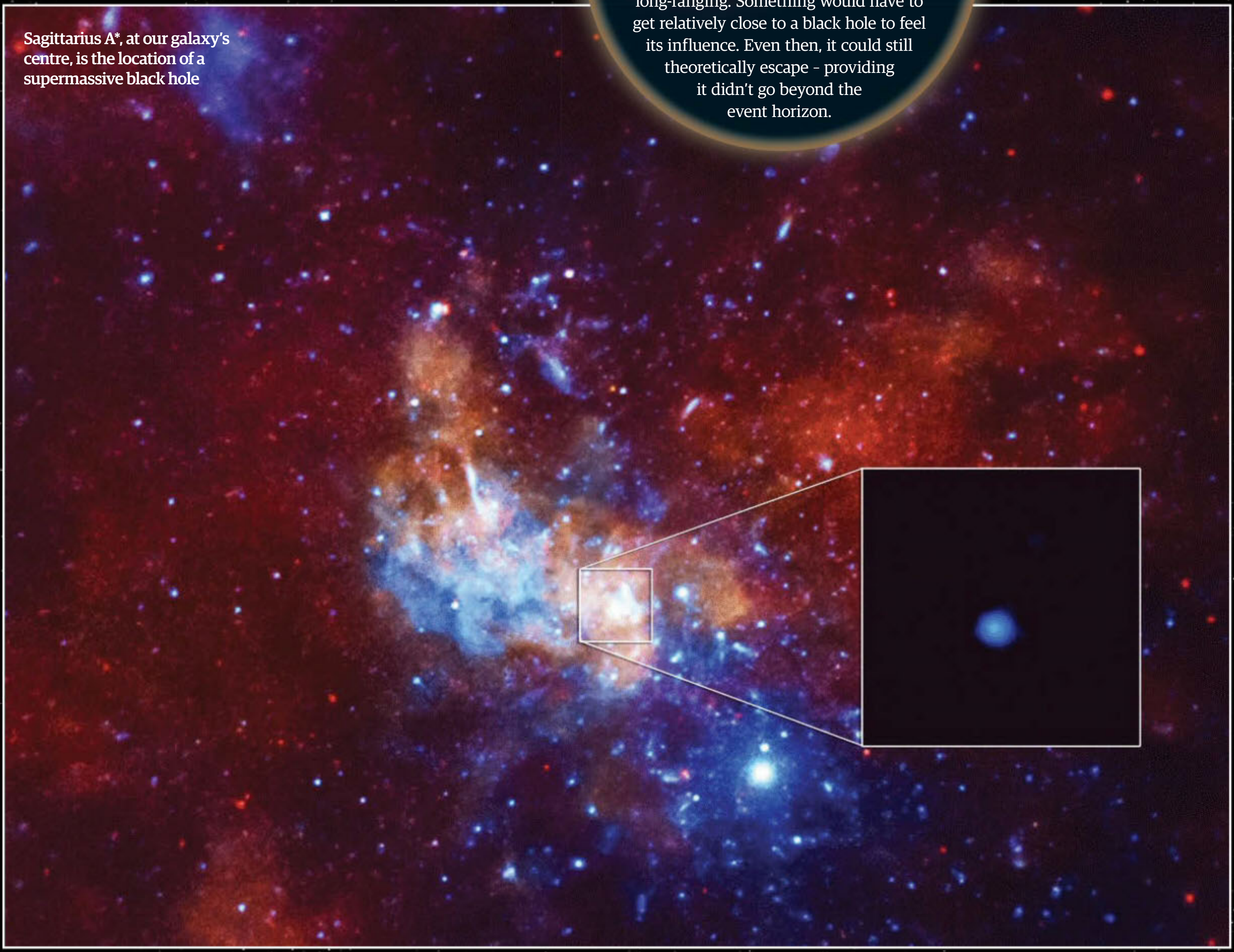
Experiments and observations continue to show that Einstein was right.

So if gravity is a warp in space-time it will affect everything within it – including light. This is how a 'dark star' could work. German astronomer Karl Schwarzschild used Einstein's equations to derive exact gravitational solutions. Other scientists did the same. The crux of

> "Supermassive black holes at the centres of galaxies grow by swallowing gas, stars and other black holes"

They don't suck

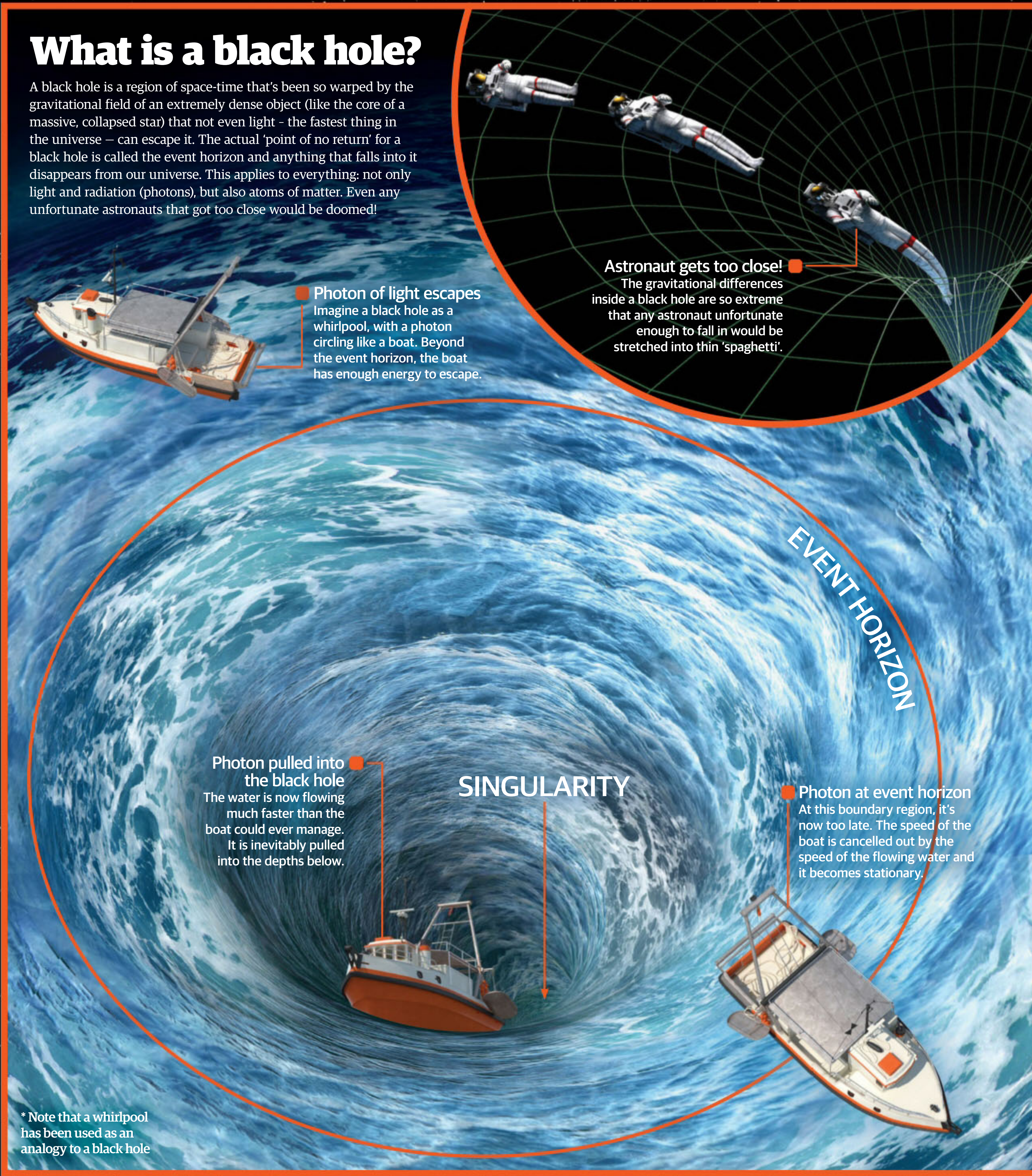
Cartoonish depictions of black holes show them sucking up everything in sight like cosmic hoovers. But this simply isn't the case. Black holes obey the known laws of physics – on the outside at least. Their gravity is extremely concentrated but not long-ranging. Something would have to get relatively close to a black hole to feel its influence. Even then, it could still theoretically escape – providing it didn't go beyond the event horizon.



Sagittarius A*, at our galaxy's centre, is the location of a supermassive black hole

What is a black hole?

A black hole is a region of space-time that's been so warped by the gravitational field of an extremely dense object (like the core of a massive, collapsed star) that not even light - the fastest thing in the universe – can escape it. The actual 'point of no return' for a black hole is called the event horizon and anything that falls into it disappears from our universe. This applies to everything: not only light and radiation (photons), but also atoms of matter. Even any unfortunate astronauts that got too close would be doomed!



Photon of light escapes
Imagine a black hole as a whirlpool, with a photon circling like a boat. Beyond the event horizon, the boat has enough energy to escape.

Astronaut gets too close!
The gravitational differences inside a black hole are so extreme that any astronaut unfortunate enough to fall in would be stretched into thin 'spaghetti'.

Photon pulled into the black hole
The water is now flowing much faster than the boat could ever manage. It is inevitably pulled into the depths below.

Photon at event horizon
At this boundary region, it's now too late. The speed of the boat is cancelled out by the speed of the flowing water and it becomes stationary.

* Note that a whirlpool has been used as an analogy to a black hole

their work is that if an object with enough mass is compressed enough, its escape velocity will match or exceed the speed of light. Once that point is reached, the object becomes a black hole. The object's radius at that point is known as the Schwarzschild radius, and this value can be calculated for any body. So, for example, the Sun's Schwarzschild radius is 2.5 kilometres (1.6 miles), and for the Earth it's nine millimetres (0.4 inches) - although neither will ever become black holes.

When a star reaches the end of its life it leaves behind a white dwarf or neutron star - depending on its initial mass. A white dwarf is a star's leftover core - usually made of carbon and oxygen. They range from 0.2 to 1.4 solar masses, are 11,000 to 28,000 kilometres (6,835 to 17,400 miles) in diameter (Earth's being 12,742 kilometres, or 7,915 miles, for comparison), and typically have a density of one tonne per cubic centimetre.

If a star is above eight solar masses, the core may exceed what is known as the Chandrasekhar limit: 1.4 solar masses. In this case, it will collapse further into a neutron star. These range from 1.4 to three solar masses and are roughly 350 to 600 million times denser than white dwarfs. Neutron stars are 20 kilometres (12 miles) in diameter and could easily fit four to five times inside the M25 motorway, which circles the city of London, UK. A neutron star's gravitational field is around 189 billion times stronger than Earth's, with an escape velocity between 100,000 and 150,000 kilometres (62,000 and 93,000 miles) per second — between one third and one half the speed of light. White dwarfs and neutron stars lie on a continuum of crushed stellar cores called 'collapsars'. Stellar-sized black holes are the end-point of this continuum. If a progenitor star is greater than ten solar masses, its core remnant may exceed what a neutron star could endure. When this happens, the remnant gets crushed below the important Schwarzschild radius: a black hole is born.

So what exactly are black holes? As we currently understand it, extreme density is the most important aspect in creating one. The general consensus in the scientific community is that black holes aren't the super-dense masses themselves, but rather the event horizons surrounding them. The event horizon isn't physical but an extreme boundary region. It's the spherically shaped domain of space-time itself surrounding the object - so it is warped by gravity. It's where the escape velocity is equal to the speed of light. As it's physically impossible for anything to move faster than light, once something goes beyond the event horizon, it disappears from our universe forever. It's a point of no return.

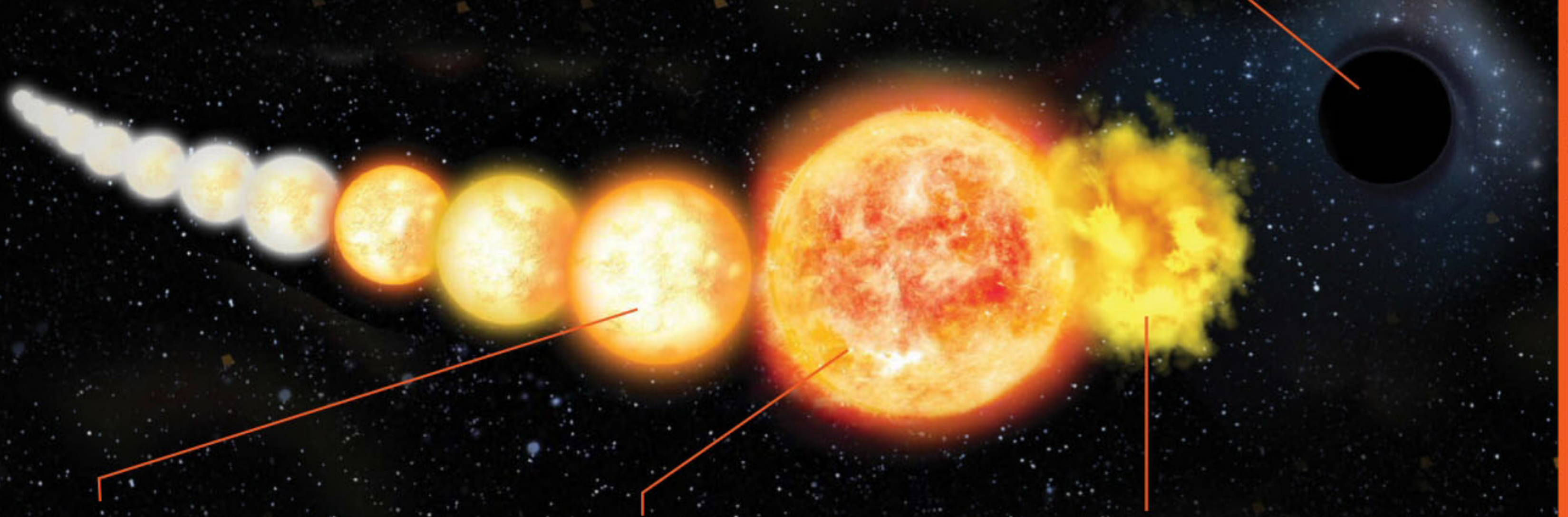
Although physicists can model the internal environments of black holes using fiendish mathematics and intense computation, they can't actually see them. So what lies beyond the event horizon is a total mystery to science. In fact, there's no direct evidence for the existence of black holes anyway. There is, however, a huge amount of strong observational and theoretical evidence.

What of the compressed mass itself, right at the heart of things? What happens to that? Does it gain weird properties? Does it become a 'singularity' - a point of zero dimensions and infinite density? Or

> "It's possible that Einstein's most lauded theory may need modification at some point in the future"

How black holes are made

Many stars leave behind white dwarfs or neutron stars at the end of their lives, depending on their initial mass. Stellar-mass black holes are a natural progression of this and originate from stars that are at least ten times the mass of our Sun. When one of these massive stars consumes all of its nuclear fuel, its outer layers contract due to decreasing temperatures and gravitational collapse. The layers implode, crushing the core into oblivion. The resulting shock wave then makes the layers explode as a supernova, hypernova or gamma ray burst.



1 Massive main sequence progenitor star
A star of at least ten solar masses is required for a black hole to form. These stars have strong gravitational fields and short lifetimes.

2 Red supergiant phase begins
After a few million years, the star consumes all of its hydrogen and becomes a red giant. It consumes other fuels formed by stellar nucleosynthesis.

3 Star explodes as supernova
When there's no more fuel, the star cools and implodes. The resulting shock wave then blows the star apart in a colossal supernova explosion.

4 Core collapses to black hole
While the shock wave results in the star's destruction, it crushes the core to become a black hole. This will be around 2-3km (1.2-1.8mi) in diameter.

does it 'rip' our space-time and become a gateway to another universe (as some scientists hypothesise)? No one knows. But the number of models and theories trying to figure this out is myriad. The only certainty at the moment is that both general relativity theory and quantum theory fail to explain this.

But black holes are strange in other ways too. White dwarfs rotate with periods lasting days to years, but much smaller neutron stars, with similar masses, can rotate hundreds of times a second due to conservation of angular momentum. That may sound complex but it's not too hard to understand.

Imagine a fixed point on a rotating body travelling at a certain speed. If that body's entire mass is compressed into a smaller volume, it will have to rotate faster in order for that fixed point to continue

They make ripples in space-time

In February 2016 the LIGO experiment made the first-ever discovery of gravitational waves – ripples in space-time predicted by Einstein's general theory of relativity. Two black holes of 29 and 36 solar masses, lying 1.3 billion light years away, orbited one another at 180,000 kilometres per second (112,000 miles per second) before colliding. In 0.2 seconds they released 50-times as much energy as the light output of every star in the known universe in the same time period.

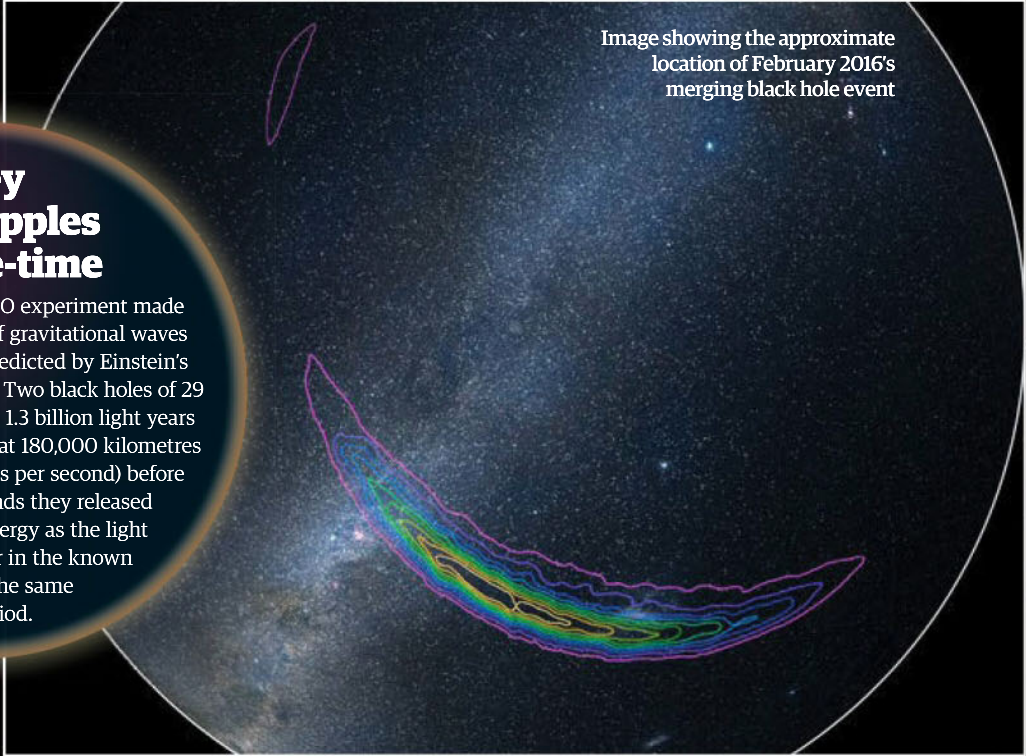
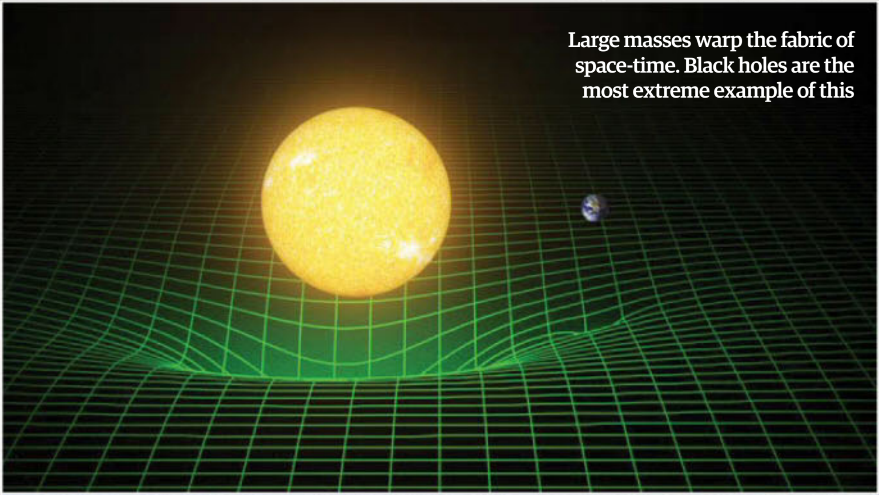
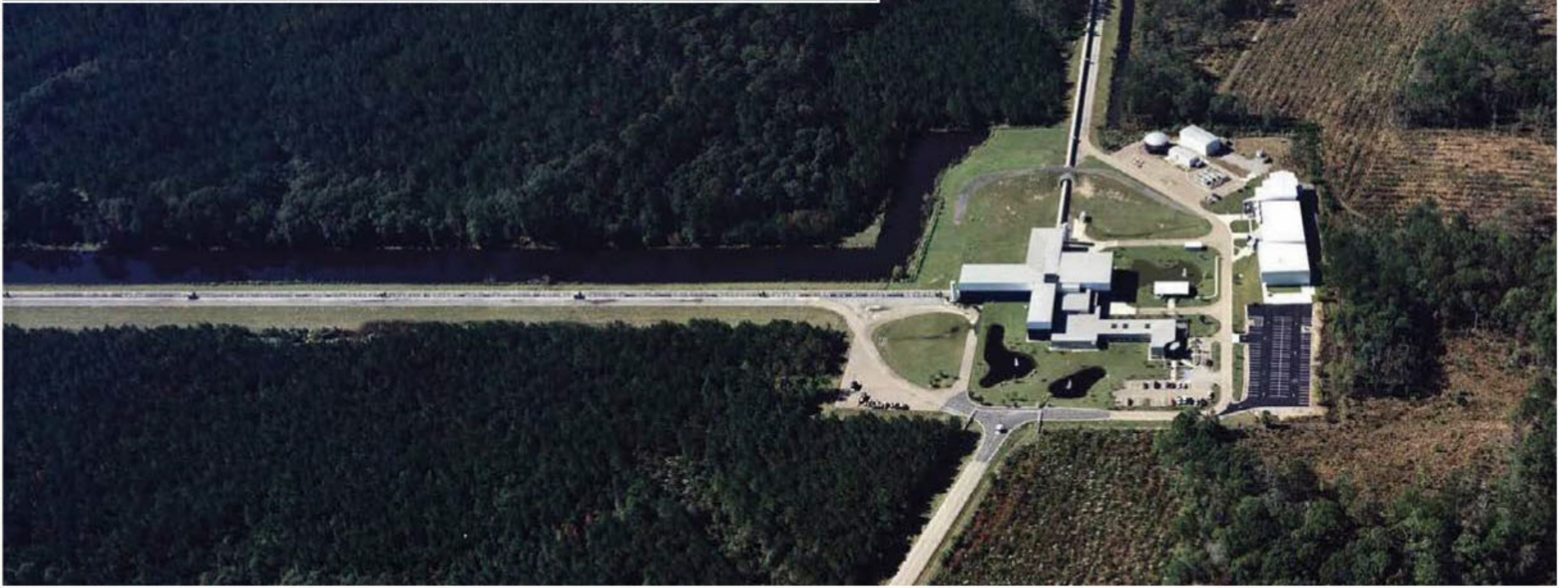


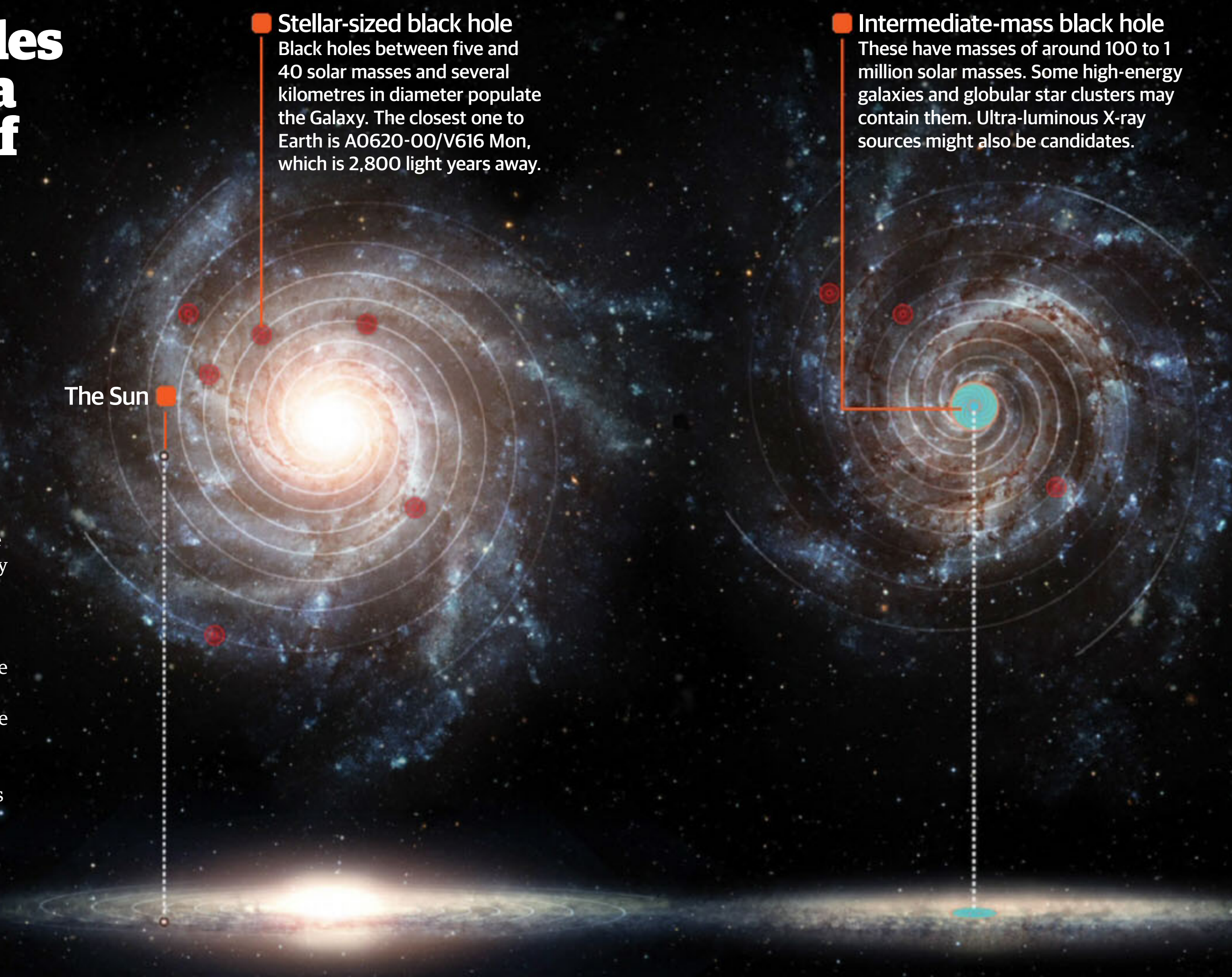
Image showing the approximate location of February 2016's merging black hole event


Large masses warp the fabric of space-time. Black holes are the most extreme example of this


One of the LIGO sites, which detected the first gravitational waves from merging black holes

Black holes come in a variety of sizes

For both stellar-sized and supermassive black holes, there will naturally be size variations. For a stellar black hole (at least five times the mass of our Sun), that will depend on the progenitor star's size. Supermassive black holes (found in galactic centres) can be millions to billions of times the mass of our Sun. For a long time scientists thought that only these two types existed, but evidence is emerging for 'intermediate-mass' black holes. Their existence isn't yet confirmed but they're thought to originate via stellar black hole collisions, massive stars merging into clusters, or as primordial leftovers from the Big Bang.



Stellar-sized black hole
Black holes between five and 40 solar masses and several kilometres in diameter populate the Galaxy. The closest one to Earth is A0620-00/V616 Mon, which is 2,800 light years away.

Intermediate-mass black hole
These have masses of around 100 to 1 million solar masses. Some high-energy galaxies and globular star clusters may contain them. Ultra-luminous X-ray sources might also be candidates.

Galaxy type: disc with bulge

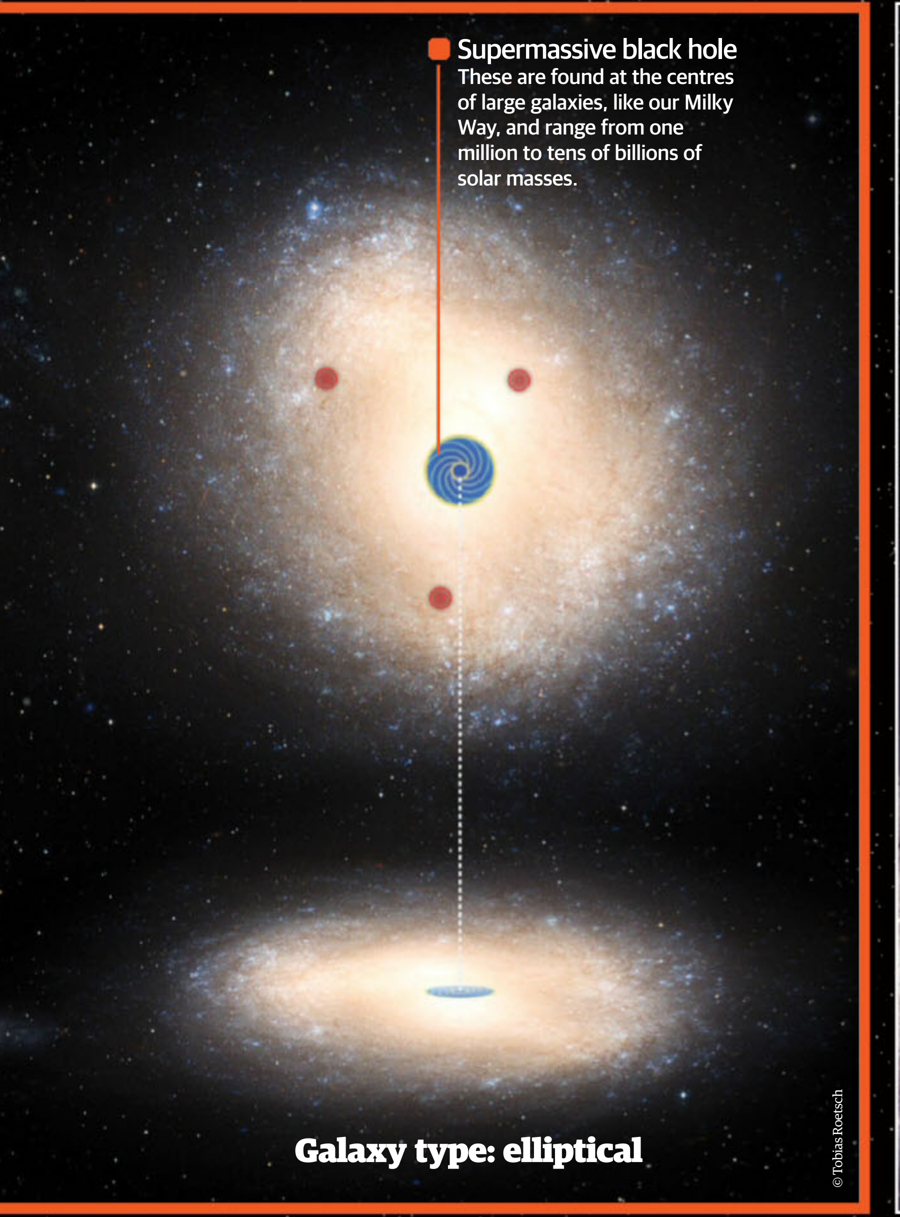
Galaxy type: bulgeless disc

Chris Adami, working with Kamil Bradler, has formulated a way that black holes can evaporate

travelling at the same speed. The exact same thing happens when a spinning ice skater pulls her arms in to speed up.

It follows then that black holes will have even higher rotation rates – which can be anywhere from half the speed of light up to close to it (300,000 kilometres per second, or 186,000 miles per second), but measurements are not easy to obtain. However, such high rotation rates affect space-time – a prediction of general relativity. Called 'frame-dragging', or the Lense-Thirring effect, it means black holes drag space-time itself around with them. This effect actually occurs for all rotating masses but it is so small that it takes the severe environment of a black hole for it to become obvious.

The region around the event horizon that experiences frame-dragging is called the ergosphere and it is lenticular-shaped. This shape is due to the fact the effect is strongest at the equator, where the black hole is spinning at its fastest, and it is weakest at the poles. Anything within the ergosphere cannot stay still. Frame-dragging is the reason that things rarely fall straight into a black hole. Rather, matter



Supermassive black hole
These are found at the centres of large galaxies, like our Milky Way, and range from one million to tens of billions of solar masses.

Galaxy type: elliptical

© Tobias Roetsch

Quasars are discs of matter swirling around black holes in distant, early galaxies

and radiation circle like soap bubbles around a plughole. The extreme gravitational gradients stretch radiation and tear matter apart – an effect known to physicists as 'spaghettification'. If there's enough matter, an accretion disc forms. Gravitational and frictional forces heat the matter to incredible temperatures before it falls in to the centre. In this way, black holes reveal their presence, especially the largest: the supermassive variety.

Determining precise masses for black holes is important. This is especially true of supermassive ones that lie at the centre of virtually every galaxy, including our Milky Way. These gargantuan monsters are millions to billions of times as massive as their stellar counterparts.

They're found at the centres of galaxies

Supermassive black holes are the largest type known, ranging from millions to billions of solar masses. Nearly every galaxy – from large to small, spiral to elliptical – has such a black hole at its centre. The one in the Milky Way's core is called Sagittarius A*. Does a galaxy create a black hole at its centre, or do galaxies form around existing, large black holes? The answer to this is still unknown.

The actual origin and formation of these black holes, as well as their relation to galaxy evolution, is an active area of research. Professor Andrew Baker of Rutgers University, New Jersey, explains: "Supermassive black holes at the centres of galaxies grow by swallowing gas, stars and other black holes. We expect that when two galaxies merge, their original black holes will also merge to form a new one." These can influence newly merged galaxies as turbulence and radiative energy from in-falling material can expel galactic gas and stop star formation. Baker was part of an international collaboration that recently used the Atacama Large Millimeter Array (ALMA) in Chile to determine the mass of the supermassive black hole in the galaxy NGC 1332, which is 73 million light years away from Earth. They found it to be 660 million solar masses.

"One of the open questions is whether galaxies and their [central] black holes grow 'in lockstep', or whether there are periods where they 'get ahead of one another'," says Baker. To determine the precise relationship between black holes and the galactic bulges in which they reside, very high-quality measurements are needed for both.

"We've demonstrated that ALMA's observations can be used to make precise black hole mass measurements – which can resolve discrepancies between estimates obtained via other methods," Baker adds. Led by Professor Aaron Barth of the University of California, Baker's team have submitted a proposal to determine much-needed masses of other black holes.

But just when you think you've figured black holes out, they turn everything on its head. Black holes actually shouldn't exist because they seemingly violate a tenet of both general relativity and quantum theory – that information cannot simply disappear from our universe. This is known as the black hole information paradox. Physicist Stephen Hawking formulated a solution from quantum theory that didn't violate a black hole's 'blackness' – it was dubbed Hawking radiation. This should make a black hole evaporate over time, thus freeing everything it once swallowed (but in a scrambled form).

How exactly would this work? "Strictly speaking [Hawking] radiation doesn't interact with the black hole itself, so it isn't really disappearing," says Professor Kamil Bradler of the University of Ottawa, Canada. Hawking's solution is further hobbled by the fact that calculating evaporation appears impossible unless general relativity and quantum theory (two otherwise extremely successful physical theories) can be made to work together – which currently they don't – in a 'theory of quantum gravity'. But Professor Chris Adami of Michigan State University and his colleague Bradler may have a solution. They sidestep quantum gravity entirely and model black holes as purely quantum mechanical objects – essentially an extension of Hawking's own process.

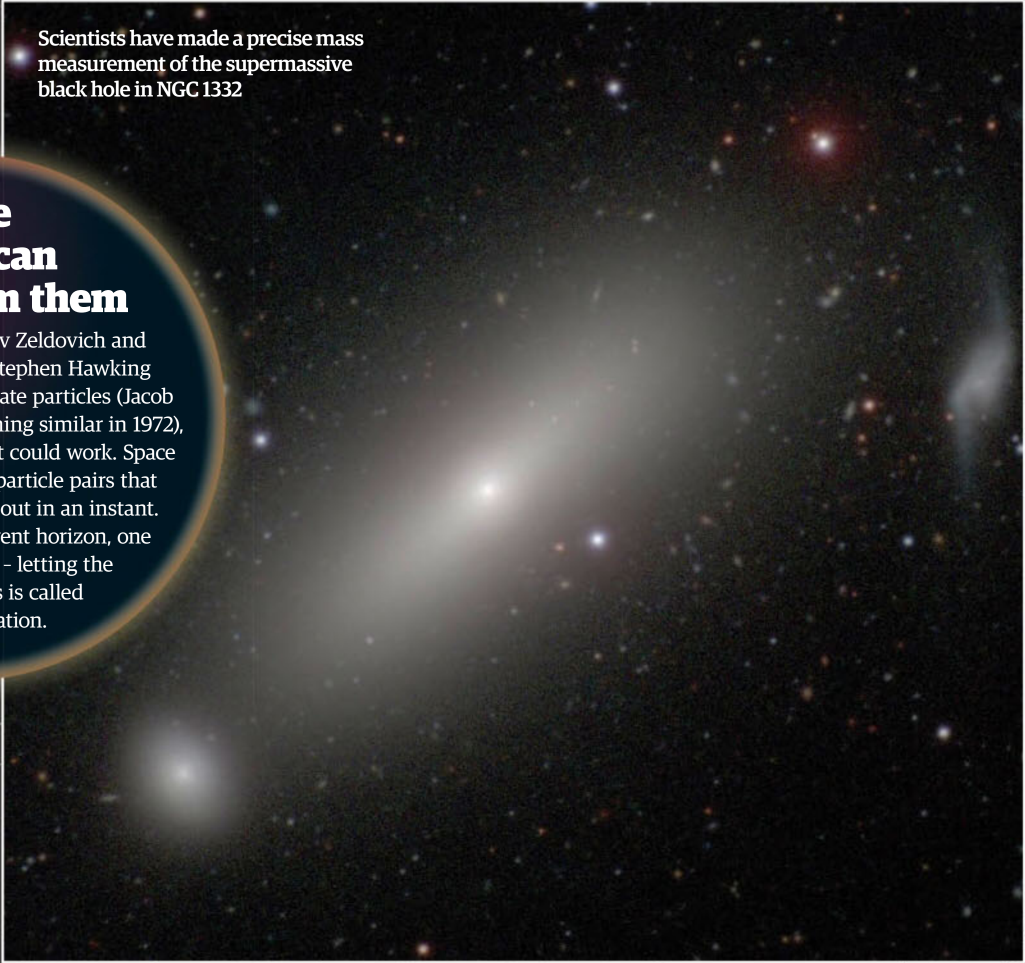
"In general relativity nothing can cross the event horizon and in that scenario a black hole can't evaporate. That poses a number of paradoxes as was observed by Jacob Bekenstein. So black holes must evaporate," says Bradler. "But then the general relativity of a black hole is invalidated." It's possible that Einstein's most lauded theory may need modification at some point in the future.

But Adami and Bradler don't let that worry them. "In our description, when a black hole evaporates, its entropy [amount of disorder], carried away in the outgoing radiation, changes in a manner predicted by Don Page. And we show that Page's theory [known as Pages Curves] should result from any consistent theory of quantum gravity," says Bradler. This is what Adami and Bradler refer to as their 'quantum back-reaction model'. They discovered that scientists worked on such models in the 1990s, but they had given up as they didn't have the benefit of quantum information theory at the time.

So with Adami and Bradler's newer model helping to get over the information paradox (and problems with Hawking's original solution), is it possible to 'probe' the interior of a black hole? It is very unlikely. "Our calculation shows that Hawking radiation encodes information about the interior, but that it's scrambled," says Bradler. This means that information representing a black hole's quantum state can't be easily 'descrambled'. It may even be computationally near impossible to do. Black holes then, are mysterious to the last.

The ALMA array may be used for precision determination of other supermassive black hole masses

> "Physicists can't see inside a black hole, so what lies beyond the event horizon is a total mystery to science"

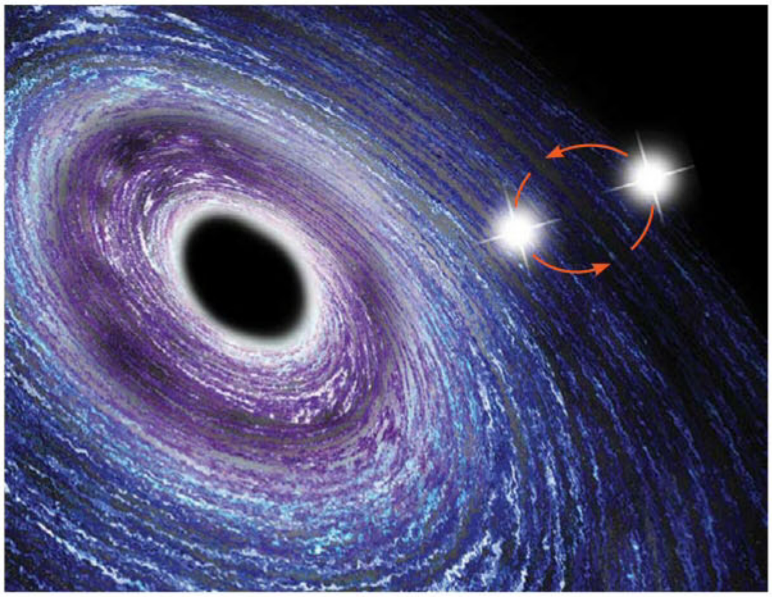

Scientists have made a precise mass measurement of the supermassive black hole in NGC 1332

Some things can escape from them

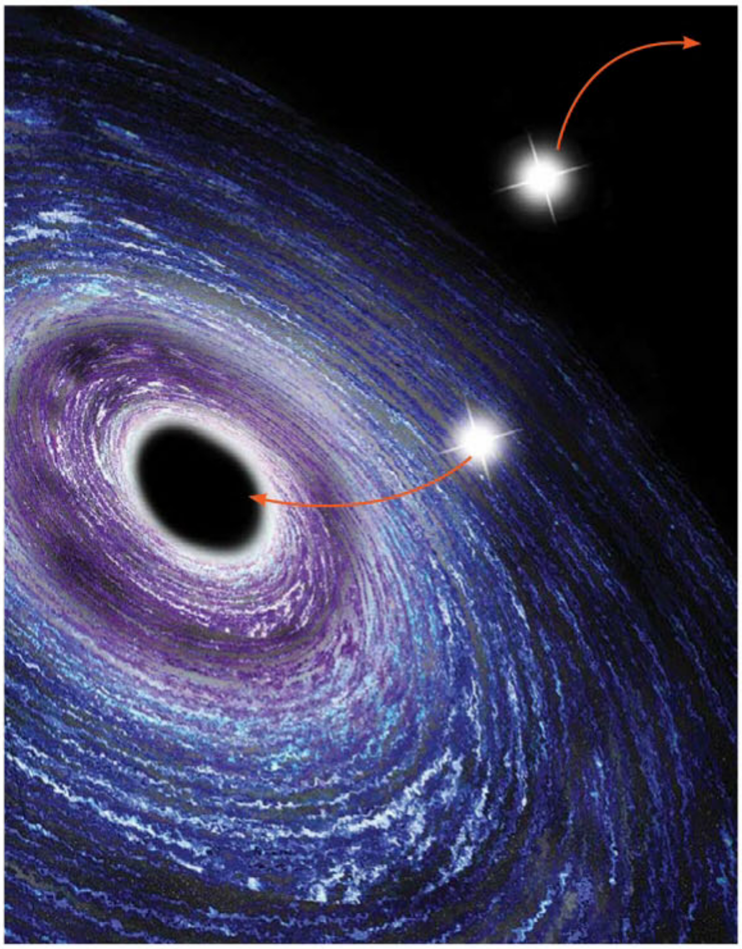
In Moscow in 1973, Yakov Zeldovich and Alexei Starobinsky told Stephen Hawking that black holes should radiate particles (Jacob Bekenstein proposed something similar in 1972), and Hawking found a way it could work. Space is filled with particle-antiparticle pairs that usually cancel each other out in an instant. But near a black hole's event horizon, one particle would fall in – letting the other escape. This is called Hawking radiation.

They throw stars out of galaxies

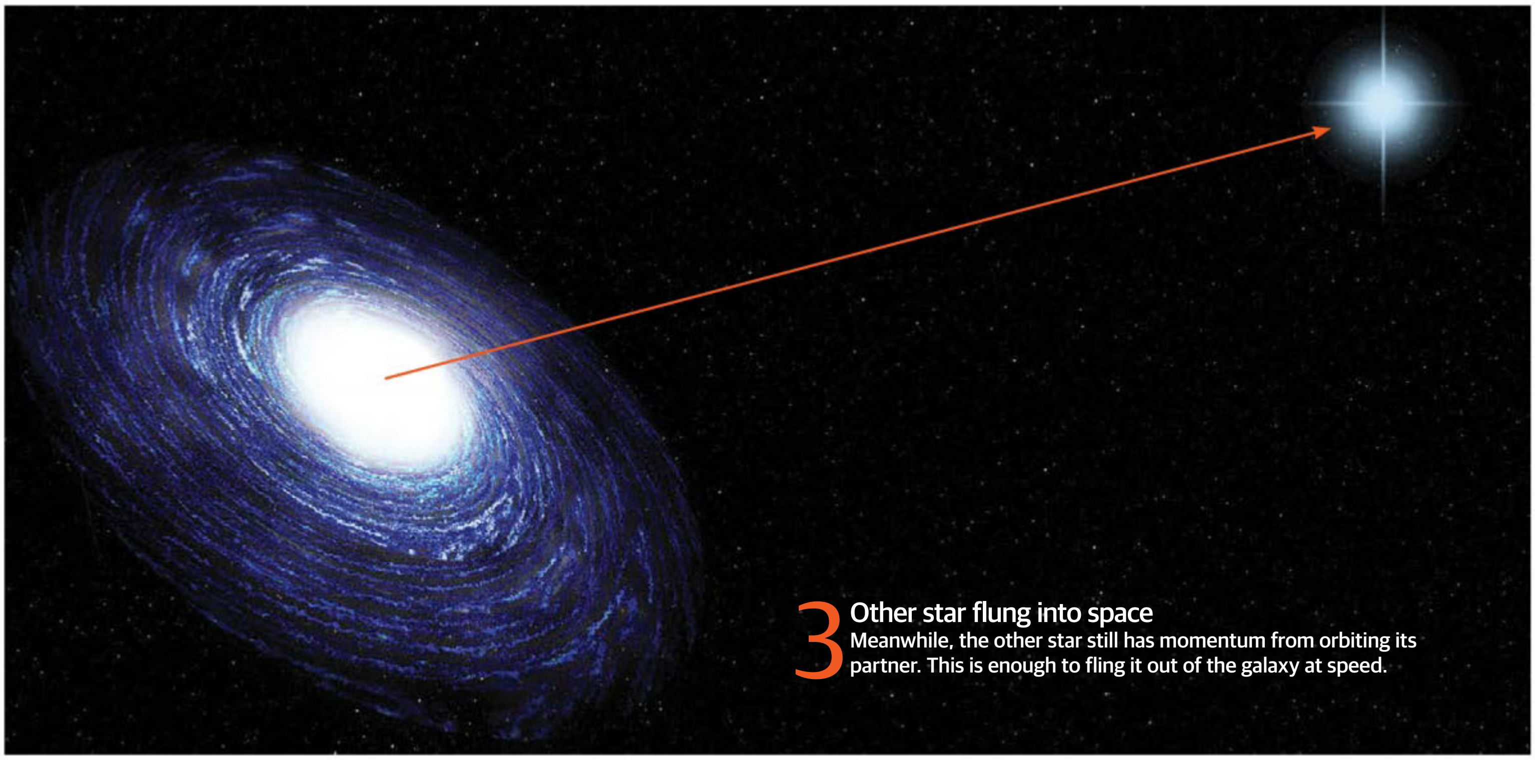
Binary star systems – two stars orbiting one another – risk having their happy union destroyed by black holes. If they get too close to a supermassive black hole, a binary system's behaviour becomes unpredictable (this is known as the 'three-body problem' and is something that crops up numerous times in physics). One binary star may tear away from its partner towards the black hole, as in mad infatuation, due to gravitation. The other, wronged, star – now without its partner to keep it stable – is flung right out of the galaxy at hundreds of kilometres per second.



1 Binary system gets too close
A binary star system travels closer and closer to a supermassive black hole. If it gets too close it can disrupt the binary system's gravitationally stable setup.



2 Star captured by black hole
One of the co-rotating stars is captured by the black hole's gravity and is stretched and torn apart, before finally falling into the black hole.



3 Other star flung into space
Meanwhile, the other star still has momentum from orbiting its partner. This is enough to fling it out of the galaxy at speed.

They're not very black

This is not strictly true - black holes themselves are truly black. But boy do they like being the centre of attention. Quasars (quasi-stellar objects) occupy the centres of distant galaxies that formed early in the universe's history, probably via galactic collisions. Their central black holes merged - pulling in matter to create quasar jets. These are 100 times as luminous as our galaxy and the size of our Solar System. Energy across the entire electromagnetic spectrum is concentrated from the accretion disc surrounding the central black hole into intense, polar jets. Some of these are directed towards us like cosmic lighthouse beams.

1 **Ancient distant galaxies collide**

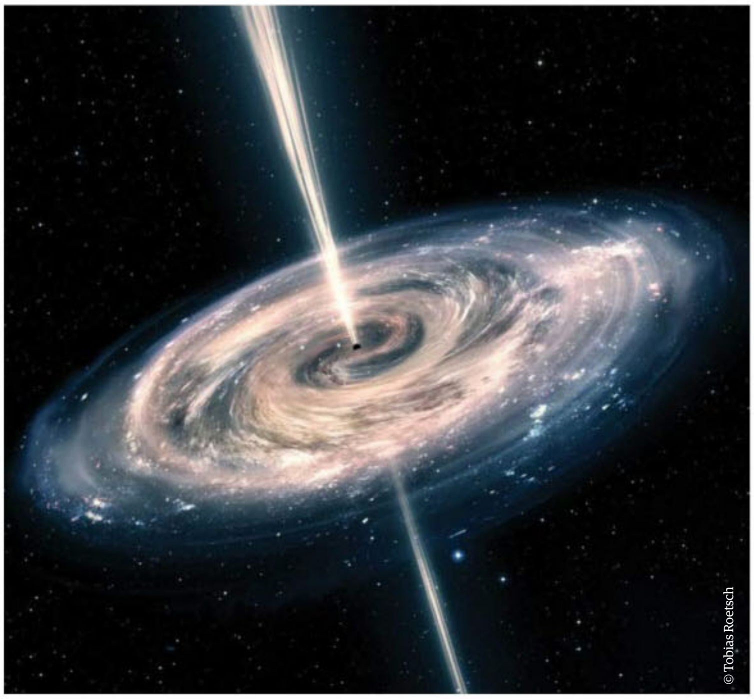
When our universe was 1 to 2 billion years old, early galaxies attracted by mutual gravitation collided with one another. Larger galaxies formed as a result.

2 **Central black holes merge**

This collision and fusion doesn't stop the galaxies; their central black holes also merge. Powerful, supermassive black holes form as a result.

3 **Supermassive black hole accretes matter**

These supermassive black holes start pulling matter into accretion discs, which heat up due to friction. The heat is so intense the disc radiates X-rays.



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4 **A quasar is born**

The black hole's intense magnetic fields collimate this radiation into powerful jets, which can be observed across the cosmos. A quasar is born.

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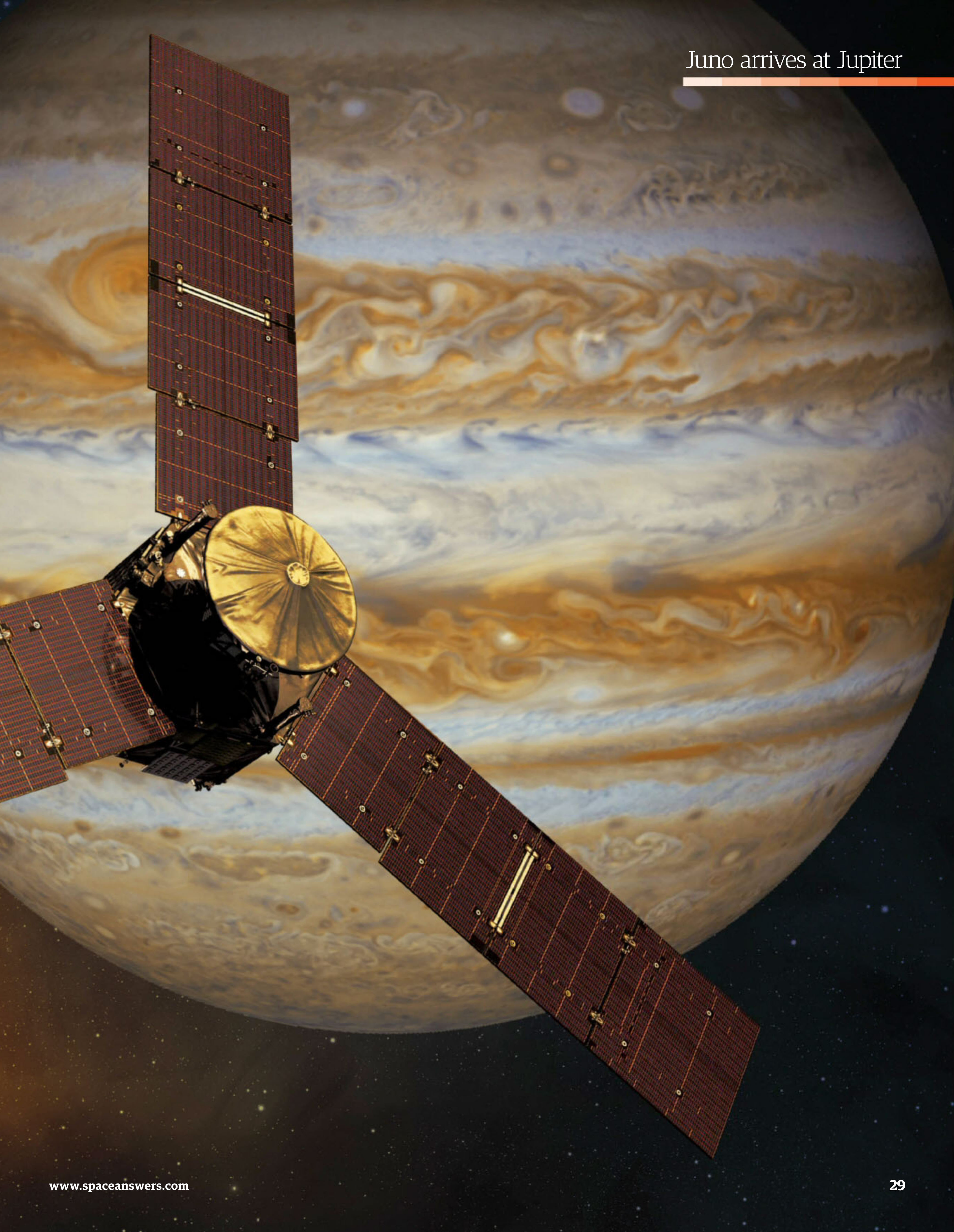
JUNO ARRIVES AT JUPITER

Arriving this summer, NASA's fastest ever space probe hopes to solve the biggest mysteries about our Solar System's largest planet

Written by Giles Sparrow



After a five-year journey across the Solar System, NASA's Juno spacecraft finally arrives at its destination, the giant planet Jupiter, this July. Equipped with an array of instruments designed to investigate Jupiter's atmospheric composition, deep internal structure and powerful magnetic field, Juno promises to transform our understanding of this colourful gas giant and hopefully answer some fundamental questions about the origin of our Solar System and others.

Launched from Earth in August 2011, Juno is the most distant space mission yet to rely entirely on solar power, and is fitted with three huge 'wings' of solar panels to harvest energy from the weak sunlight of the outer Solar System. It is only the second spacecraft to enter orbit around Jupiter – the first was Galileo, which sent back a wealth of images and other scientific measurements between 1995 and 2003 and also launched an atmospheric probe into the planet's upper atmosphere shortly after its arrival.

While the Galileo spacecraft studied both the giant planet and its spectacular system of moons, Juno (named after the wife of Jupiter in Roman mythology) will focus on Jupiter alone, following an orbit that takes it closer to the planet and sends it over the poorly studied polar regions.

"Some of the main ideas for Juno came from leftover questions raised by Galileo, and especially the atmospheric probe," recalls Dr Scott Bolton of the Southwest Research Institute, principal investigator on the mission and the man largely responsible for turning the Juno mission into a reality. "I'm also a scientist on the Cassini mission, and when that passed by Jupiter in 2000 on its way to Saturn, I was putting together the programme of observations. Others wanted to see if we could get some other science that turned out not to be possible, but thinking about how to do that basically put us on the road to putting together a new Jupiter mission. We put it all in one proposal back in 2003."

"Juno is the most distant space mission yet to rely entirely on solar power and is only the second spacecraft to enter orbit around Jupiter"

Prior to launch, the Juno spacecraft awaits fuelling with propellant for its built-in manoeuvring engines

So what were the questions that Galileo left unanswered? One of the most important was the planet's atmospheric make-up. "The composition measured by the Galileo atmospheric probe came as a surprise to pretty much everyone," explains Dr Bolton. "Jupiter is basically dominated by hydrogen and helium like the Sun, but it's enriched with heavier elements in a way that we can't explain. And to make the problem even worse, we don't know the abundance of a key molecule – water – and from that the amount of oxygen."

The Galileo probe's failure to detect water is a particularly big issue because water (or frozen ice) plays a key role in most current models for the formation of the Solar System. It's thought to have been abundant beyond the 'snow-line' of the infant Solar System (the boundary where simple molecules condense), and so we'd expect it to be present in the planet today. "One theory is that the atmospheric probe just happened to go down into a dry spot," points out Bolton, "but there's always the possibility that Jupiter's like that everywhere. So the question of how you explain what Galileo measured, and how we fill in the water and oxygen measurements, was a main driver in figuring out Juno. The primary science goal is to do with the formation of Jupiter, and going after the recipe for the Solar System in general."

Bolton adds, "All the elements that Jupiter got enriched with are enriched by about the same factor, and we don't know how it got that way. It's an important question because those heavier elements are what we're made out of – it comes right back to us. How do you make planets, and how do these materials get concentrated?"

Since it won't be deploying a probe to directly measure the atmosphere, Juno must instead analyse its composition from a distance, using its Microwave Radiometer instrument. Microwaves are short-wavelength radio waves that pass through Jupiter's upper cloud layers and can therefore reveal the chemistry of the atmosphere down to depths of about 600 kilometres (373 miles) – corresponding to pressures about 200 times greater than Earth's atmosphere. And probing the distribution of chemicals in Jupiter's deep atmosphere should also help to answer another important question, since it may reveal the presence of a structure below the cloud tops. "At present we have no idea how deep the zones and belts and features like the Great Red Spot go," Dr Bolton elaborates. "It's not that Galileo really failed to answer those questions – it just wasn't equipped to ask them in the first place."

Jupiter's overall internal structure is just as important to understanding the way in which it formed – it's clear that below the outer atmosphere (from perhaps 1,000 kilometres, or 621 miles, down) the planet's hydrogen and helium condense

How Juno will unlock Jupiter

The spacecraft's unique set of instruments aims to look below the surface of Jupiter and answer some long-standing questions

How deep do the weather systems go?

Jupiter is famous for its colourful weather systems – not just the enormous storms such as the Great Red Spot, but also the general pattern of creamy-white 'zones' and reddish-brown 'belts' that run parallel to the equator. The two types of band effectively move in opposite directions around the planet, but are they just surface weather features or a reflection of much deeper structures within the planet's liquid interior?

How Juno will solve it: The Microwave Radiometer and the JIRAM should both reveal concentrations of various chemicals associated with weather systems deep beneath the surface.

Is there a core?

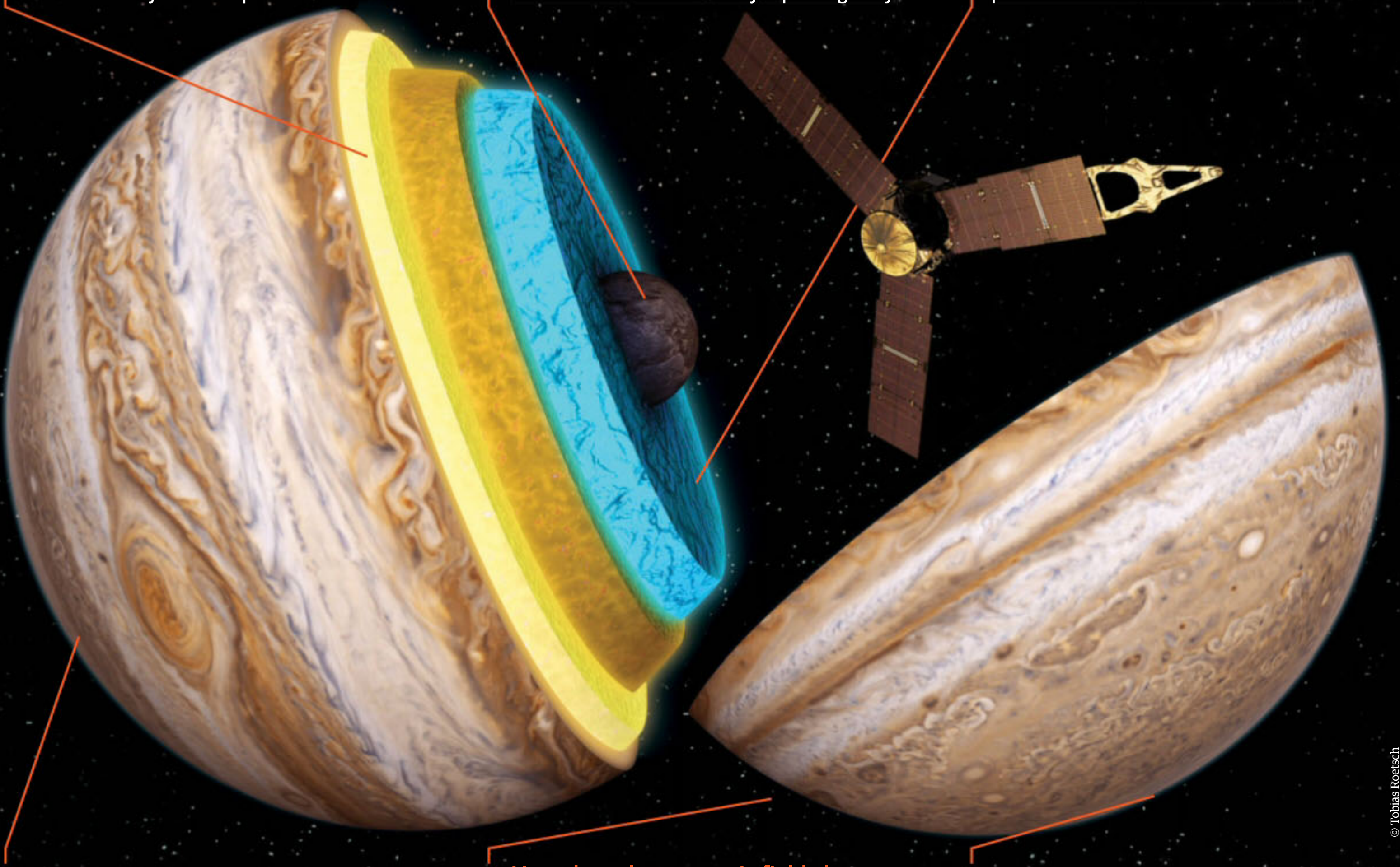
Although most astronomers agree that Jupiter formed around a solid core (rather than coalescing from a cloud of gas and ice), the presence of a core remains unproven. Measuring the core's size and density from its effect on Jupiter's gravity could answer key questions about the planet's formation, but it might not be that simple – some studies suggest solid cores of giant planets can erode over time.

How Juno will solve it: Measuring the changing wavelengths of radio signals sent from Juno to Earth will show how the probe speeds up or slows down as it is affected by Jupiter's gravity.

Where is all the water?

Galileo's atmospheric probe measured surprisingly little water during its descent into the clouds. This could be connected to the fact that the probe entered an atmospheric 'hot spot' – a distinctly warm region that may be drier than elsewhere – but that's just a theory. Jupiter should contain lots of water if it formed from the same ice-rich material as its moons, so if Juno doesn't find it, that will be a big mystery.

How Juno will solve it: Juno's Microwave Radiometer will measure radiation at six wavelengths – the signal strength will reveal the presence of water and other chemicals.



© Tobias Roetsch

What is the polar weather like?

As Galileo and most flybys have been close to the equatorial plane, we know very little about the weather at Jupiter's poles – our best views come from the Pioneer 11 flyby some 42 years ago and mosaics stitched together from Cassini's flyby in 2000. We know that Saturn's poles hide some of the largest storms in the Solar System, so it would be surprising if violent, colourful Jupiter doesn't have some secrets hidden at its poles.

How Juno will solve it: JunoCam will image Jupiter as the craft approaches within 5,000km (3,100mi) of the cloud tops. Mosaic images should provide detail of 25km (16mi) per pixel.

How does the magnetic field alter around the poles?

While Galileo mapped the structure of the magnetic field around Jupiter's equator, its polar regions are poorly understood. Better mapping of the 'polar magnetosphere' could explain how far inside the planet the magnetic field is created and clarify the planet's internal 'dynamo' – the pattern of swirling electrical currents that are thought to generate magnetic fields.

How Juno will solve it: Mounted on the end of one of its three 'wings', Juno's magnetometer will detect the strength and direction of magnetic field lines as the spacecraft moves along its orbit.

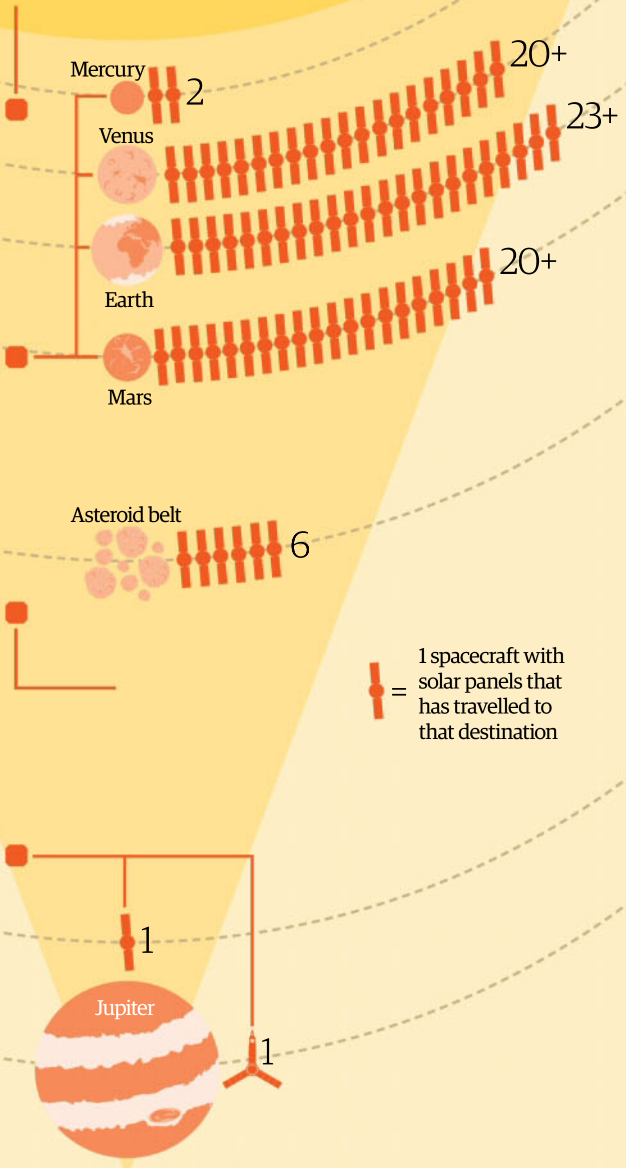
What particles cause the aurorae?

Jupiter's northern and southern lights are far more powerful than Earth's – when high-speed particles channelled by the magnetosphere strike gas molecules in the upper atmosphere, they release visible light and energetic ultraviolet and X-rays. We want to understand the properties of the particles and the role of volcanic moon Io's eruptions, which are thought to contribute huge amounts of sulphur atoms to the light shows.

How Juno will solve it: Instruments JADE and JEDI will measure the speed and energy of particles around the craft and detect elements such as hydrogen, helium, oxygen and sulphur.

Solar-powered spacecraft

Juno is the latest and most ambitious of many solar-powered spacecraft launched since the dawn of the Space Age



Falling power
The amount of energy from the Sun follows an 'inverse square' rule – at double the distance from the Sun it is four times weaker.

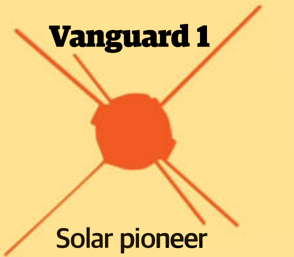
Close to the Sun
Missions to Mercury, Venus, and Mars, as well as Earth satellites, can easily generate energy using solar power.

Alternative power
Most spacecraft to the outer Solar System have previously relied on generators that produce energy using the heat from radioactive material.

Fading power
So far, Rosetta and Juno are the only spacecraft to have used solar power in the cold, dark space beyond the asteroid belt.

= 1 spacecraft with solar panels that has travelled to that destination

Vanguard 1

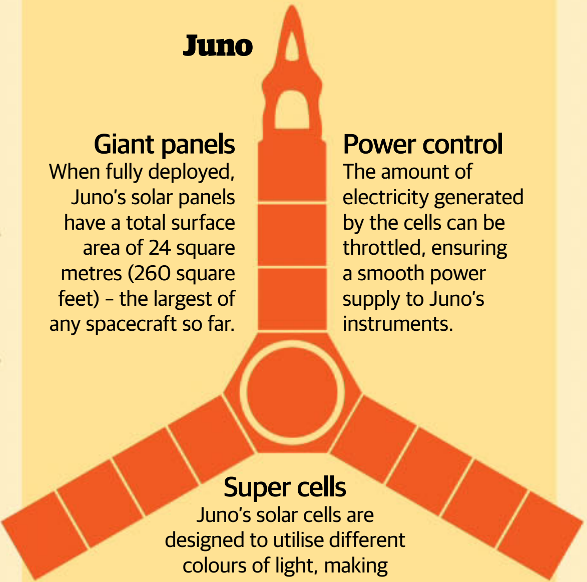


Solar pioneer
Launched in 1958, Vanguard 1 was a grapefruit-sized Earth satellite that powered its radio transmitter using six primitive solar cells.

Rosetta

Previous record
ESA's Rosetta mission ventured into the outer Solar System in order to rendezvous with its target, Comet 67P, in 2014.

Juno



Giant panels
When fully deployed, Juno's solar panels have a total surface area of 24 square metres (260 square feet) – the largest of any spacecraft so far.

Power control
The amount of electricity generated by the cells can be throttled, ensuring a smooth power supply to Juno's instruments.

Super cells
Juno's solar cells are designed to utilise different colours of light, making them more efficient than previous generations.

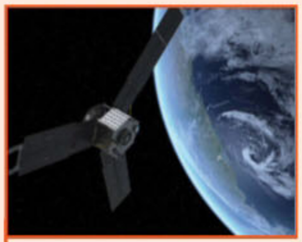
Juno's major milestones

In the five years since its launch from Earth in 2011, Juno has undertaken several crucial manoeuvres to put it on course for gas giant Jupiter

5 August 2011
Juno launches from Cape Canaveral using the powerful Atlas V 551 rocket. Within 43 minutes of launch, it escapes Earth into an independent orbit around the Sun.

2011 to 2013
Juno deploys its enormous solar 'wings' – reaching a 20m (65ft) wingspan – and begins to charge its batteries for the long journey ahead using energy from the Sun.

August to September 2013
The Juno spacecraft fires its main engine for two course corrections, which sends it towards a rendezvous with our home planet.



10 October 2013
Juno swings past Earth in a 'slingshot' manoeuvre, which uses the planet's gravity to boost the craft's speed, sending it on a flight path towards Jupiter.

under enormous pressure to form a global ocean of liquefied gases, and deeper still that the liquid hydrogen molecules break apart to create a swirling sea of 'liquid metallic' hydrogen carrying powerful electric currents. But is there a solid core at the centre of all this – and if there is, was it the nucleus around which the gases accumulated, or did it form later by heavier elements sifting down through the lighter ones? In order to answer this question, the Juno team will make use of an ingenious radio experiment that relies on the way Jupiter's internal structure affects its overall gravity and alters the flight path of the spacecraft itself.

A final key area for Juno's investigations is Jupiter's enormous magnetic field. Swirling patterns – called eddy currents – in the liquid metallic ocean are thought to generate this magnetic field, whose influence can be detected as far away as the orbit of Saturn. Electrically charged particles trapped and accelerated by the field create deadly radiation belts around Jupiter's equator and intense aurorae (northern and southern lights) where they stream down into the atmosphere around the poles.

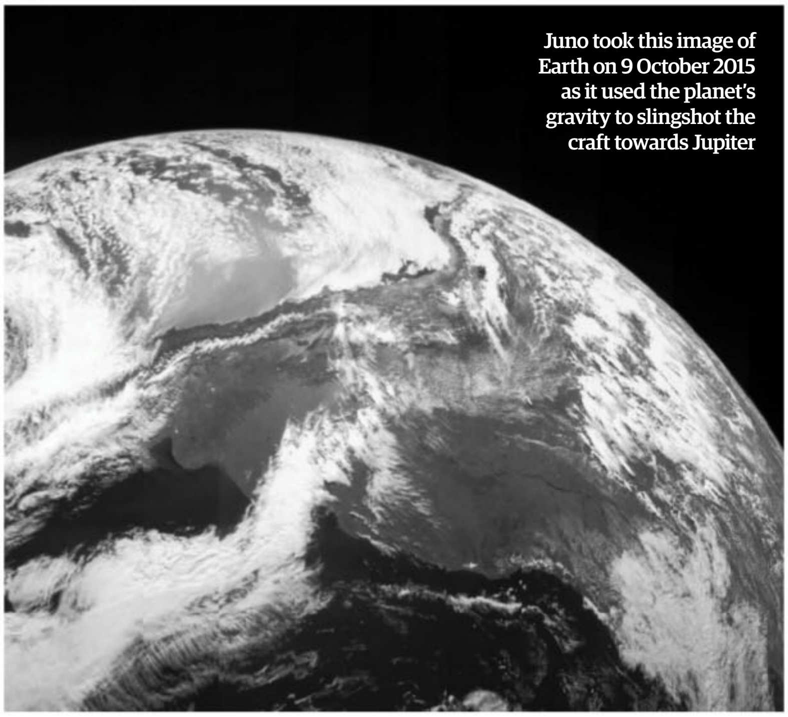
"Galileo orbited around the equator and we got a handle on the magnetosphere there," says Dr Bolton, "but it didn't tell us anything about the polar magnetosphere, which is very important because it feeds into Jupiter's powerful aurorae." Many of Juno's science instruments are therefore designed to measure various aspects of the magnetic field and the particles and aurorae associated with it.

The radiation belts present one final challenge – the very survival of the spacecraft and its instruments. With no atmosphere to protect it, Juno will be bombarded by high-energy particles that could damage its delicate electronics. For this reason, as much of the instrumentation as possible is packed into the Juno Radiation Vault – a box with thick titanium walls that sits at the heart of the spacecraft.

The spacecraft's 14-day orbit will also be highly elliptical, coming close to Jupiter as it flies above the poles, but venturing beyond the orbit of Callisto (the outermost of Jupiter's giant moons) as it crosses the equatorial plane where the radiation belts are thought to be concentrated. "We're very much an armoured tank going to Jupiter," elaborates Dr Bolton. "Of course, we don't know how bad the radiation will be, but based on our models we think we're protected with margin."

Thirteen years since its inception and five years since its launch, Juno's primary mission is planned to last for just 20 months. However, in that short period it should transform our understanding of Jupiter – and perhaps the Solar System as a whole. It's sure to be a fascinating mission.

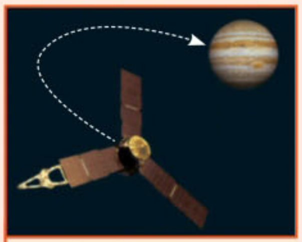
> "Juno promises to transform our understanding of gas giant Jupiter and explore the origin of our Solar System"



Juno took this image of Earth on 9 October 2015 as it used the planet's gravity to slingshot the craft towards Jupiter

Technicians test the deployment of one of the huge solar arrays to prepare Juno for its 2011 launch

© NASA; JPL-Caltech; Lockheed Martin; Bill Ingalls; Malin Space Science Systems; ESA



2014 to 2015
Juno crosses interplanetary space on a curving trajectory towards Jupiter. The craft is now four years into its journey and is getting further and further away from the Sun.

13 January 2016
Juno becomes the most distant solar-powered spacecraft ever launched, overtaking the record set by ESA's Rosetta mission at the outer limits of its orbit.

February to May 2016
Juno fires its engine for two more course corrections. This is to refine its approach trajectory to Jupiter and ensure that the craft reaches its target.

28 May 2016
Juno enters the region of space that is dominated by the gravitational influence of gas giant Jupiter, rather than the Sun. It becomes caught in the planet's gravity.

4 July 2016
Juno burns its engine for 35 minutes to enter orbit around Jupiter. It will make two 53.5-day orbits before a second burn drops it into its final 14-day trajectory.

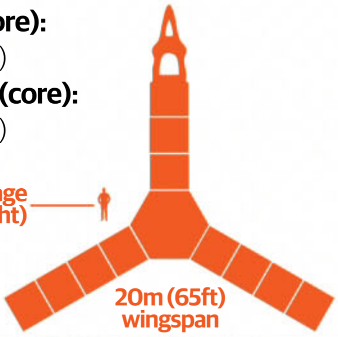
USER MANUAL

Juno spacecraft

Written by Dominic Reseigh-Lincoln

THE SPECS

Launch: 5 August 2011
Launch rocket: Atlas V 551
Target: Jupiter
Operators: NASA / JPL
Programme cost: $1.1bn (£760mn)
Component: Multiple components
Finished construction: 2011
Height (core):
3.5m (11.5ft)
Diameter (core):
3.5m (11.5ft)



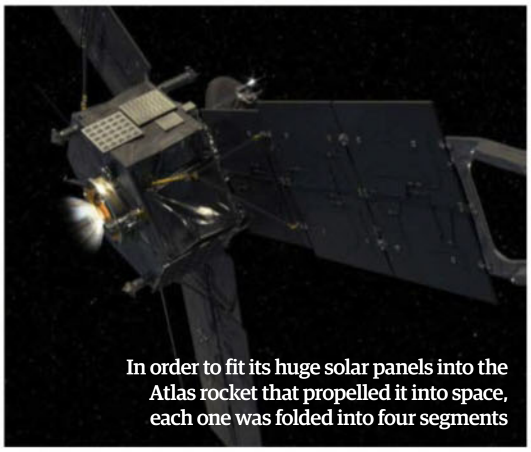
For NASA and its Jet Propulsion Laboratory, the Jupiter Near-Polar Orbiter (Juno) is more than just another analytical study far out in the depths of space – it's a step forwards for alternative fuels in deep space travel and could very well change the way we design such craft in the decades to come.

Interestingly, the estimated $1.1 billion (£760 million) programme isn't the first NASA effort to study the imposing gas giant sitting far across the expanse of our Solar System. From 1995 to 2003, the proverbial 'old faithful' Galileo probe was held in Jovian orbit for a staggering eight years before eventually being deorbited and torn apart in the gas giant's turbulent atmosphere. Galileo revealed a treasure trove of information about the largest planet in our corner of space, including the theory of a liquid ocean as well as providing a greater understanding of how its unique magnetosphere conducts itself around the chaos of its composition. So what will Juno be doing when it finally enters Jovian orbit in July this year? The new craft will be studying the planet in incredible detail in an attempt to understand the true nature of the Milky Way's most violent planet.

Juno will be investigating the core mass of the planet in the hope of better understanding how such an object formed in the furnace of our Solar System's creation, while also studying the ratio of oxygen to hydrogen (another area that could share more insight into that early formation era). The planet's magnetic

> "Juno will investigate the core mass of Jupiter in the hope of understanding how such an object formed"

Juno was tested in a thermal vacuum chamber to simulate the harsh space environments the probe will encounter

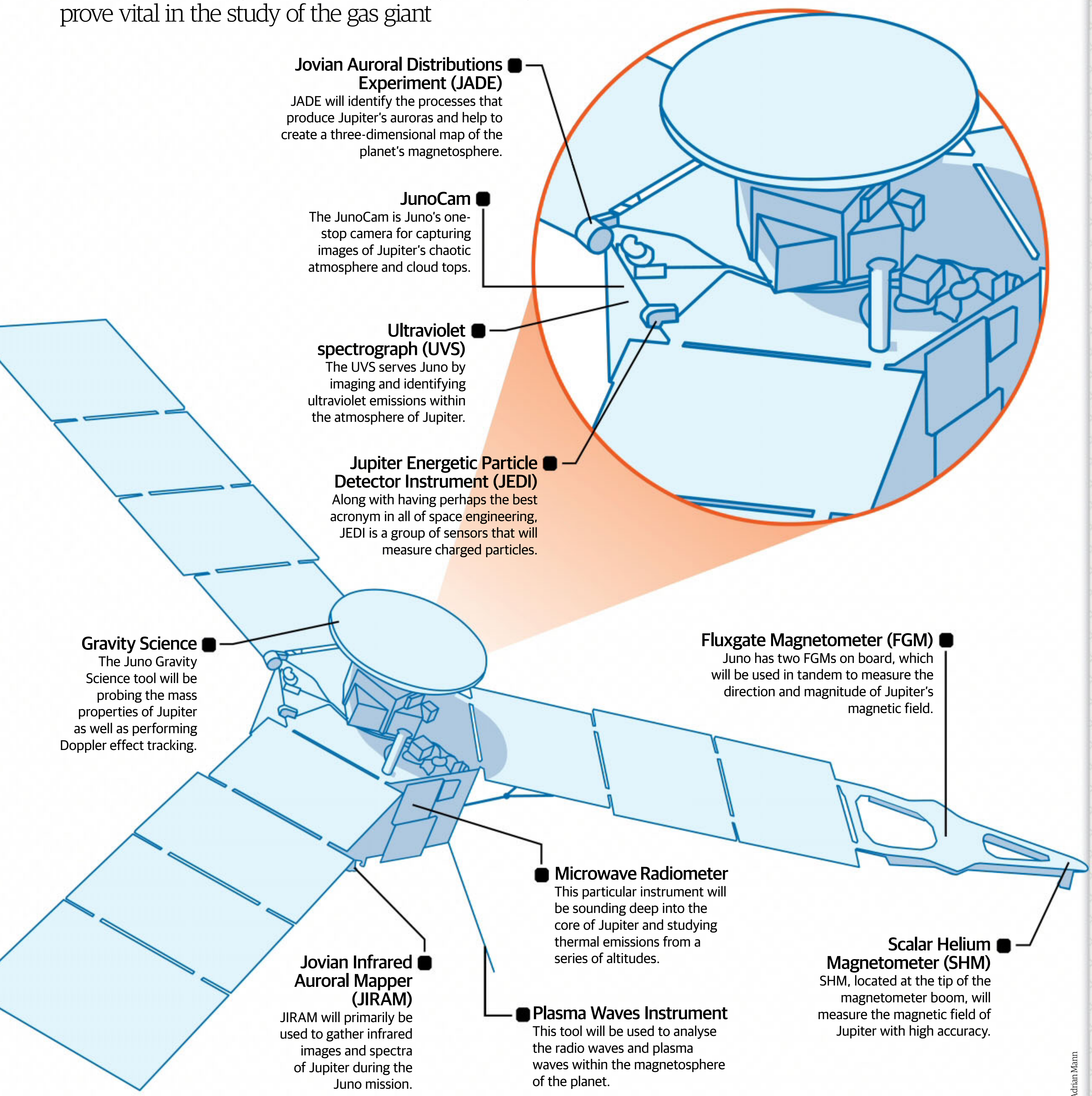


In order to fit its huge solar panels into the Atlas rocket that propelled it into space, each one was folded into four segments

A technician inspects one of Juno's insulating blankets before it is installed on the Magnetometer

Anatomy of Juno

Its instruments may not be revolutionary, but they will prove vital in the study of the gas giant



Jovian Auroral Distributions Experiment (JADE)
JADE will identify the processes that produce Jupiter's auroras and help to create a three-dimensional map of the planet's magnetosphere.

JunoCam
The JunoCam is Juno's one-stop camera for capturing images of Jupiter's chaotic atmosphere and cloud tops.

Ultraviolet spectrograph (UVS)
The UVS serves Juno by imaging and identifying ultraviolet emissions within the atmosphere of Jupiter.

Jupiter Energetic Particle Detector Instrument (JEDI)
Along with having perhaps the best acronym in all of space engineering, JEDI is a group of sensors that will measure charged particles.

Gravity Science
The Juno Gravity Science tool will be probing the mass properties of Jupiter as well as performing Doppler effect tracking.

Fluxgate Magnetometer (FGM)
Juno has two FGMs on board, which will be used in tandem to measure the direction and magnitude of Jupiter's magnetic field.

Microwave Radiometer
This particular instrument will be sounding deep into the core of Jupiter and studying thermal emissions from a series of altitudes.

Jovian Infrared Auroral Mapper (JIRAM)
JIRAM will primarily be used to gather infrared images and spectra of Jupiter during the Juno mission.

Plasma Waves Instrument
This tool will be used to analyse the radio waves and plasma waves within the magnetosphere of the planet.

Scalar Helium Magnetometer (SHM)
SHM, located at the tip of the magnetometer boom, will measure the magnetic field of Jupiter with high accuracy.

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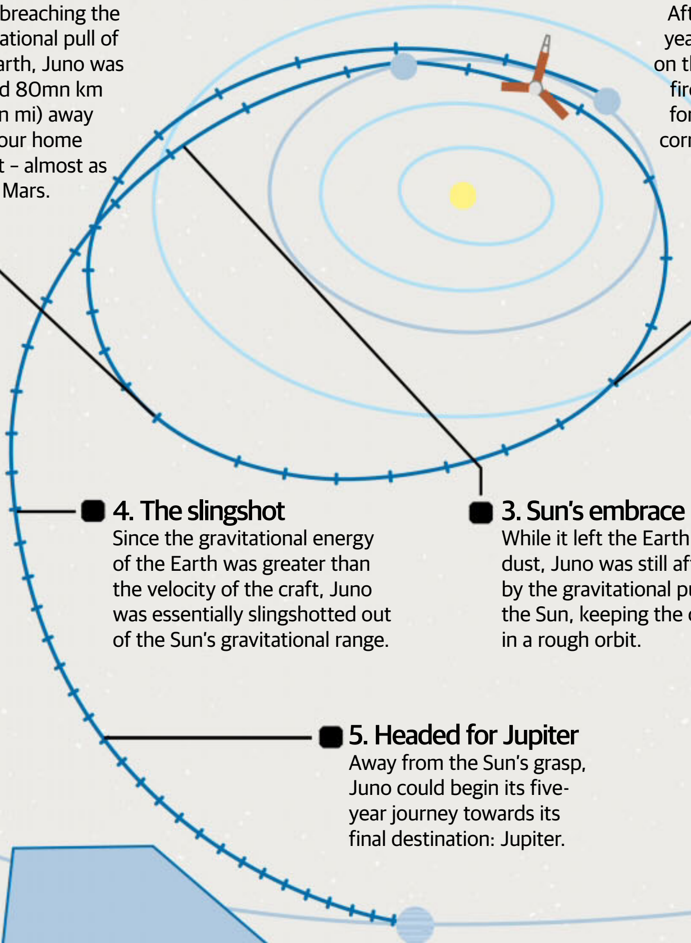
How Juno performed a gravity assist manoeuvre



1. Getting into position
After breaching the gravitational pull of the Earth, Juno was carried 80mn km (50mn mi) away from our home planet – almost as far as Mars.

2. Course correction
After around two years of travelling on this route, Juno fired its boosters for a brief course correction to align it for an Earth encounter.

3. Sun's embrace
While it left the Earth for dust, Juno was still affected by the gravitational pull of the Sun, keeping the craft in a rough orbit.

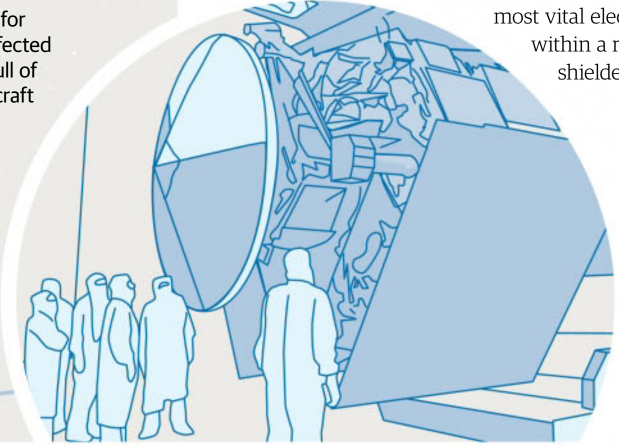
4. The slingshot
Since the gravitational energy of the Earth was greater than the velocity of the craft, Juno was essentially slingshotted out of the Sun's gravitational range.

5. Headed for Jupiter
Away from the Sun's grasp, Juno could begin its five-year journey towards its final destination: Jupiter.

and gravitational fields are also of great interest to NASA – Juno will be studying the depth of Jupiter's gravitational pull to the dynamics of its deep core, as well as tracking its magnetic field to see just how far into the planet such a process originates. That study will also, if we're lucky, bring us a little closer to understanding the wider effect of the dynamo theory (the process whereby a celestial body creates a magnetic field).

That's not it for Juno either – NASA is planning to construct a three-dimensional picture of Jupiter's magnetosphere for the first time, following on from the data collected by Galileo more than a decade ago. There are even plans to apply Einstein's general theory of relativity to Jovian rotation, as well as further tests to study the planet's temperature. It's a pretty tall order, even for the biggest of spacecraft, but it's got plenty of established technology up its sleeve to get the Jovian job done.

For a start, the craft will be undertaking a rather unusual orbit – a highly elliptical polar orbit to be precise – which has been chosen specifically to help Juno avoid most of Jupiter's highly radioactive regions. Since radiation levels will still be incredibly high (even in the comparatively safer band between the poles), Juno will keep its most vital electronics within a radiation-shielded vault.



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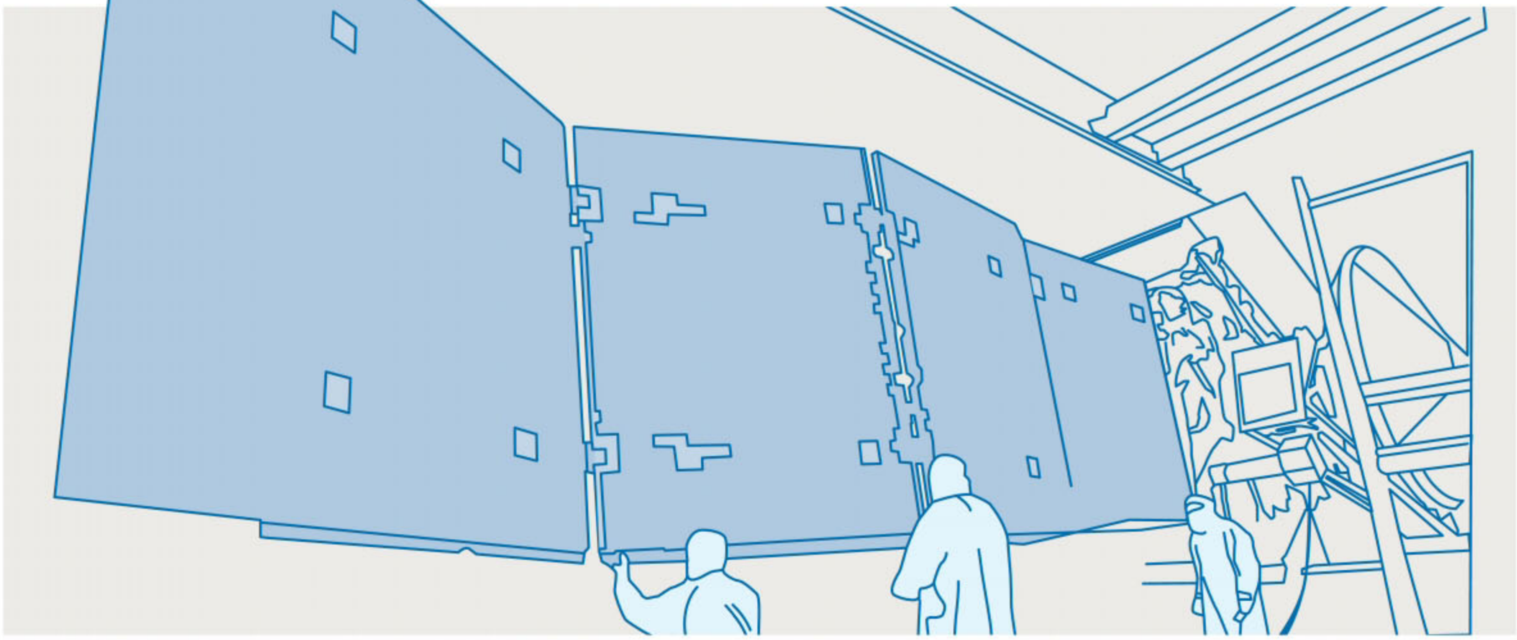


This vault hasn't been thrown in for good measure – its inclusion in the primary Juno design forms part of NASA's Vision for Space Exploration, which states any spacecraft travelling beyond low-Earth orbit must have sufficient radiation shielding in order to ward against failure out in the field. Interestingly, Juno will also be in perpetual spin when it begins its orbit, a procedure that's vital for the craft's onboard instruments to get an equal chance to study the planet in depth.

Those instruments won't be anything new to those familiar with NASA's many other probes and spacecraft, but they will still prove vital on board a vehicle attempting to unlock some of the universe's most unusual secrets. Juno will be packing seven main instruments in total, with each one facilitating those all-important goals NASA has planned.

However, it's in its use of solar power that Juno will make its biggest waves. At a distance of 588 million kilometres (365 million miles) – that's five times the distance between the Earth and the Sun – Juno will be receiving 25-times less sunlight than we do here on terra firma. As such, the choice to include solar panels as the primary means of energy may seem a little reductive but advances in solar cell design is making all the difference, even now as it hurtles towards its destination.

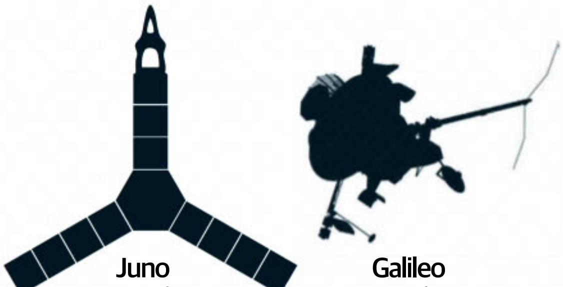
With that great distance to battle, Juno has three large solar panels at its disposal (each of which is 8.9 metres or 29.2 feet long), which will power the craft for the entirety of its planned two-year mission. Those cells are the latest in solar power technology and are 50 per cent more effective at utilising sunlight than those used in previous missions.

Considering Juno will be the first mission of this type and distance to not utilise traditional radioisotope thermoelectric generators – even its predecessor Galileo used such a propulsion system – the craft will be proving the potential of solar power, even in the deepest of space.

Atlas V 551 rocket
The space rocket will launch Juno on its five-year journey from Cape Canaveral, Florida.

Head to head

When it comes to size, Juno outshines the previous Jupiter craft, Galileo, as its three solar panels give the craft a 20m (65ft) wingspan. In terms of weight, Juno also has the edge with an impressive 3,625kg (8,000lb) launch mass, while Galileo weighed in at a respectable 2,220kg (4,900lb) – for comparison, a double-decker bus weighs 12,000kg (26,460lb). In terms of time, Galileo took six years to reach Jupiter, while Juno will make the trip in less than five.



Juno
3,625kg

Galileo
2,220kg

TOP TECH

Solar panels:
the tech changing deep space travel forever

In January 2016, Juno became the most distant solar-powered craft from the Sun. The record was previously held by ESA's Rosetta probe at a distance of 792mn km (492mn mi). With 18,698 solar cells at its disposal, spread over three panels, Juno will have more than enough energy to power its mission. At Earth distance, those silicon and gallium arsenide cells generate 14kW of energy, but that will be much lower when it reaches Jupiter.

Vital statistics

2 hours
The time it will take Juno to fly from one pole of Jupiter to another
=
It will spin **400** times during this period

486 watts
The power being generated by Juno when it arrives
=
The same as eight 60W bulbs

3.5m
The height of Juno
=
That's slightly taller than a basketball hoop

340kg
The combined weight of all three panels
=
Roughly the same as three fridges

620km/h
Top speed of solar winds around Jupiter
=
Over three-times faster than a family hatchback

HOW TO...

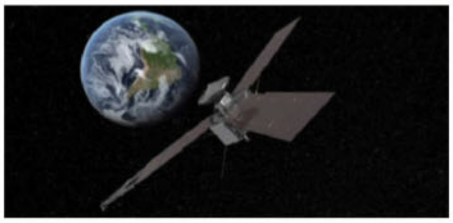
Get a spacecraft into an orbit

1 The big launch

On 5 August 2011, Juno lifts off from Cape Canaveral beneath an Atlas V 551 rocket. After one minute and 33 seconds, the two main boosters detach and fall away. The main engine falls away at four minutes and 26 seconds, and after just 40 minutes Juno is out of Earth orbit.

2 Earth flyby

Two years later, the Juno spacecraft performs an Earth flyby on 9 October 2013. This gives the craft the large speed boost it needs to reach Jovian space. The flyby brings the craft within 559km (347mi) of Earth before flinging it back out into deep space.



3 Entering Jovian orbit

On 4 July 2016, Juno will approach Jupiter and begin an orbital insertion burn in order to slow its speed and enable the craft to enter the 14-day polar orbit around the planet. The craft will then begin a mission consisting of 37 orbits between Jupiter's poles.

4 End of mission

After 24 months, NASA plans to terminate Juno by removing it from elliptical orbit and manoeuvring it into the planet's turbulent atmosphere, where it will burn up. This is in order to avoid the possibility of terrestrial bacteria taking root outside of our planet.

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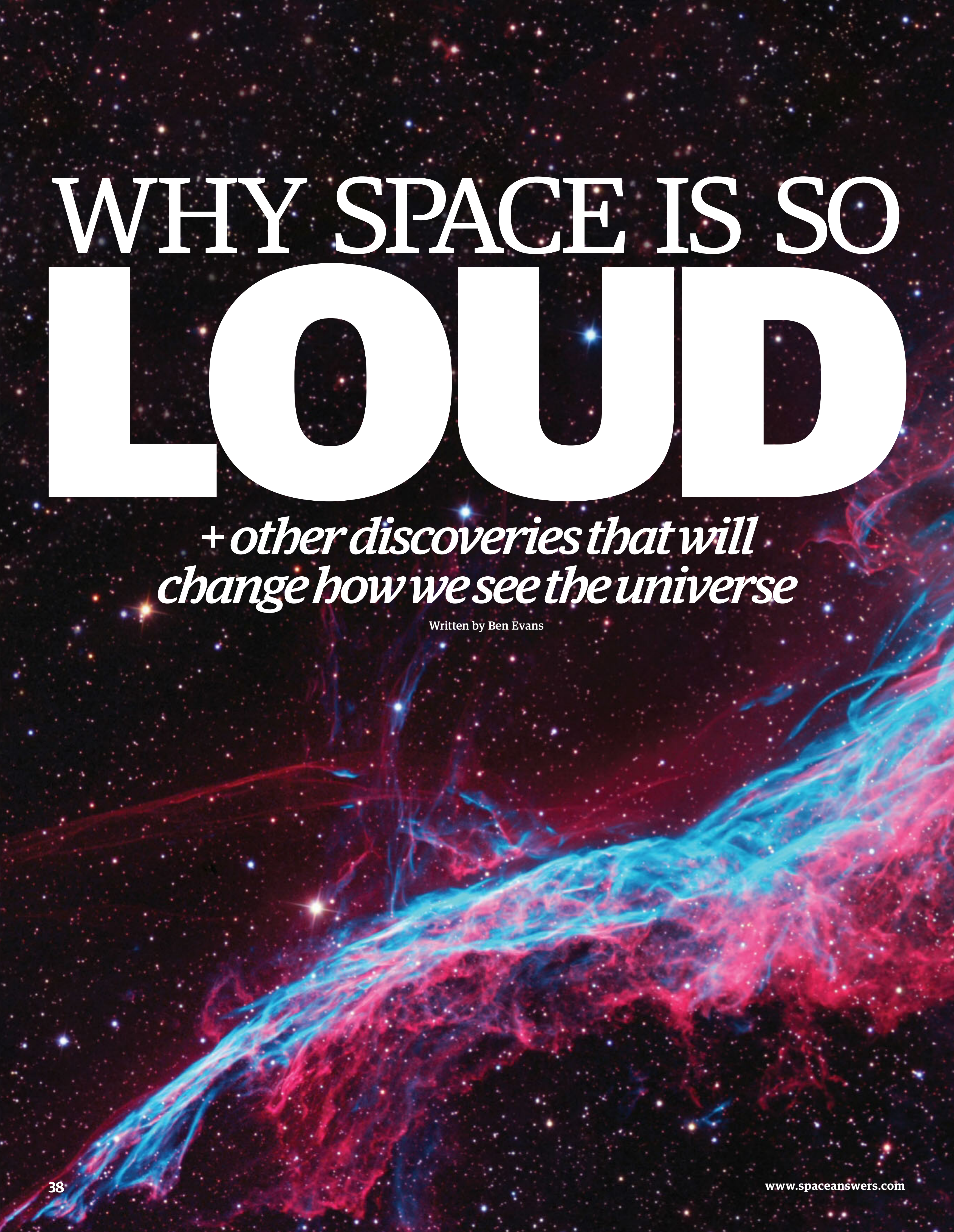


WHY SPACE IS SO LOUD

+ other discoveries that will change how we see the universe

Written by Ben Evans

We solved what causes the space roar

When NASA sent a balloon to the edge of space in July 2006, its mission was to study heat from ancient stars and galaxies. It would uncover clues about how the universe evolved from the Big Bang until halfway through its 13.8-billion-year life span.

Aboard the balloon, the Absolute Radiometer for Cosmology, Astrophysics and Diffuse Emission (ARCADE) detector spent several hours observing a small patch of sky from 36,576 metres (120,000 feet). What it found was tantalising.

Instead of faint signals from the universe's infancy, ARCADE revealed a powerful 'hiss' of low-frequency radio waves. A radio 'background' – the combined output of our Milky Way and other galaxies – was not unexpected, but the signal was six-times stronger than it should have been. Primordial stars and gaseous clouds were ruled out. Even the sum of every known radio wave-emitting galaxy could not account for such intensity. ARCADE's own accuracy fell under scrutiny, but was corroborated by other data.

Nicknamed the 'space roar', its cause remains unclear. Maybe it comes from an unexplained radio source, deep in the universe, or maybe our models of calculating cosmic background radiation are inaccurate. It makes it more difficult to examine the universe's youth, but understanding the roar may help us understand how galaxies evolved billions of years ago. This is just one of the mysteries that, if solved, would change how we see the universe.

Why the Sun's outer layer is so hot

From the Latin word 'crown', the corona – the Sun's outer atmosphere – is the crowning jewel of our parent star. However, its greatest riddle is its temperature. This exceeds 1 million degrees Celsius (1.8 million degrees Fahrenheit), far hotter than the 6,000 degrees Celsius (10,800 degrees Fahrenheit) of the Sun's visible surface, the photosphere. The Second Law of Thermodynamics states that heat should not flow outwards from a cooler to a hotter region. Therefore, the explanation must lie in wave or magnetic energy.

Waves were observed by the SOHO probe in 1997. Computer models and spacecraft data have shown that waves – including low-frequency Alfvén waves – can move large amounts of energy into the Sun's corona and sustain high temperatures. However, many remain localised, transient and cannot explain the corona's uniform heat.

Another possibility is that the magnetic field induces electric currents. These currents collapse, allowing the field to 'reconnect' with other magnetic poles to release energy. The SOHO craft observed thousands of reconnections, some of which heated coronal plasmas to 1 million degrees Celsius (1.8 million degrees Fahrenheit).

Other theories focus on short-lived, fast-moving jets, called spicules. The Solar Dynamics Observatory revealed them heating the corona and highlighted the important role played by a thin 'transitional' region above the photosphere. The upcoming Solar Probe Plus mission may bring us closer to resolving this great mystery.

Layers of the Sun

Corona

The corona begins around 2,100km (1,300mi) above the photosphere and is the Sun's outermost layer.

From 500,000°C (900,000°F) to over 1,000,000°C (1,800,000°F)

Transitional region

This region is 100km (62mi) thick and sits between the chromosphere and the corona. It is characterised by an abrupt increase in temperature.

From 7,700°C (14,000°F) to 500,000°C (900,000°F)

Chromosphere

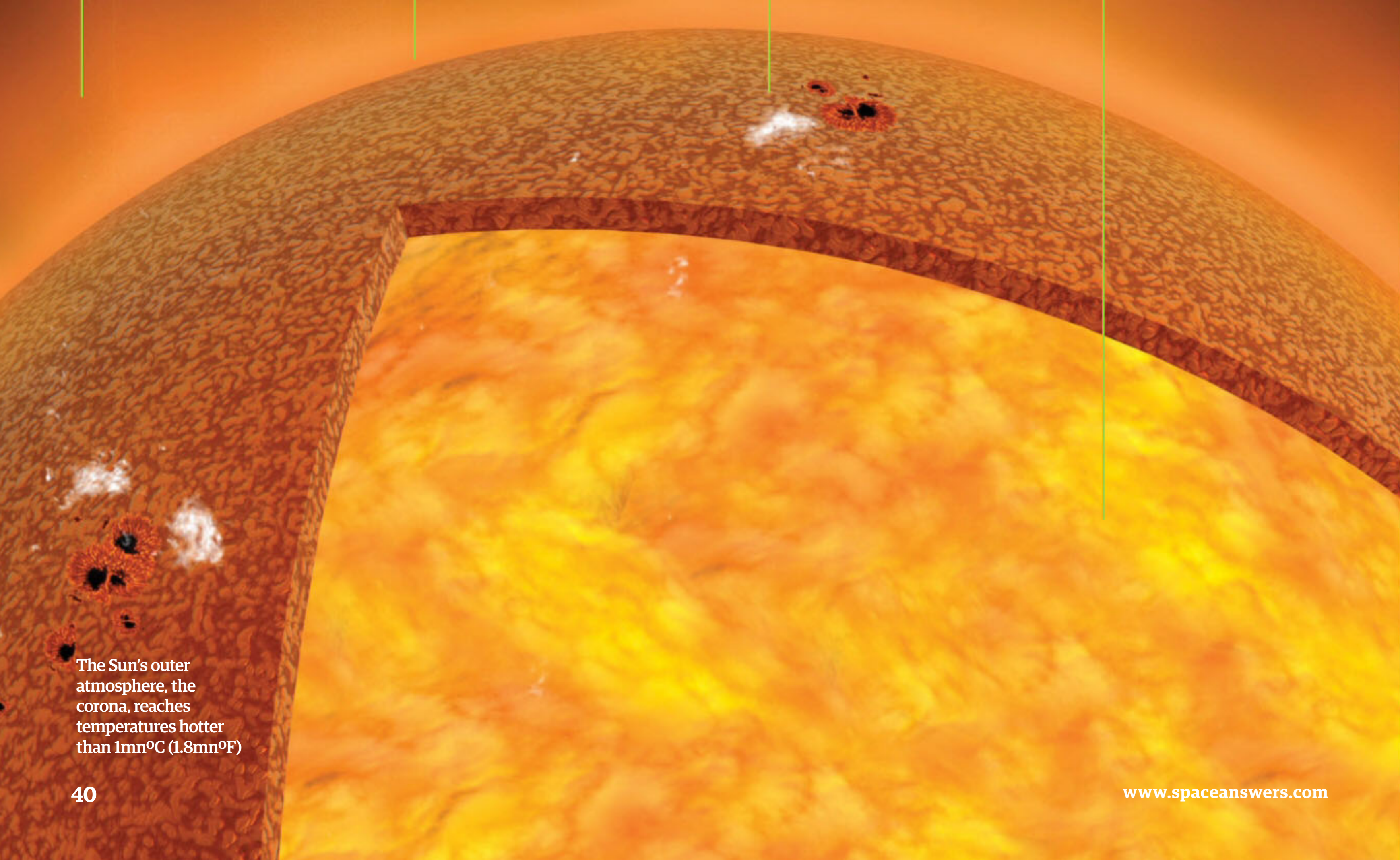
This extends 400km (250mi) to 2,100km (1,300mi) above the photosphere and temperatures get hotter with higher altitude.

From 3,700°C (6,700°F) to 7,700°C (14,000°F)

Photosphere

The photosphere is the deepest layer of the Sun that we can directly observe directly. It is often described as the Sun's 'surface'.

From 3,700°C (6,700°F) to 6,200°C (11,000°F)



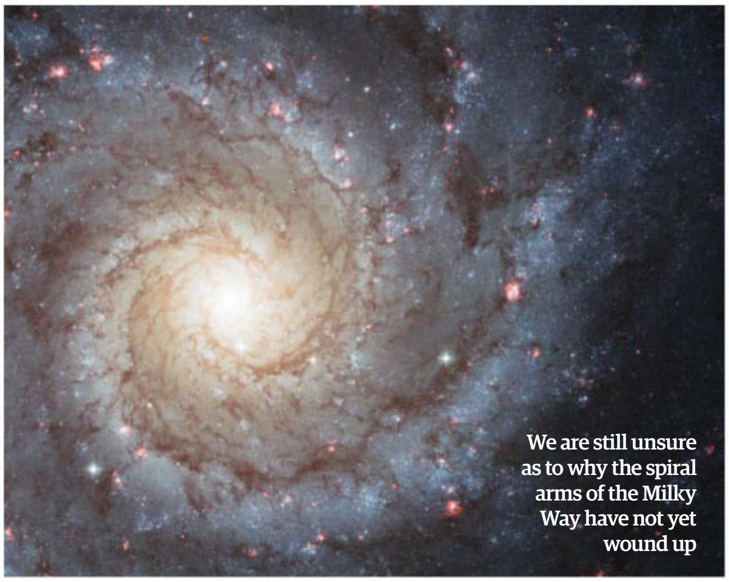
The Sun's outer atmosphere, the corona, reaches temperatures hotter than 1mn°C (1.8mn°F)

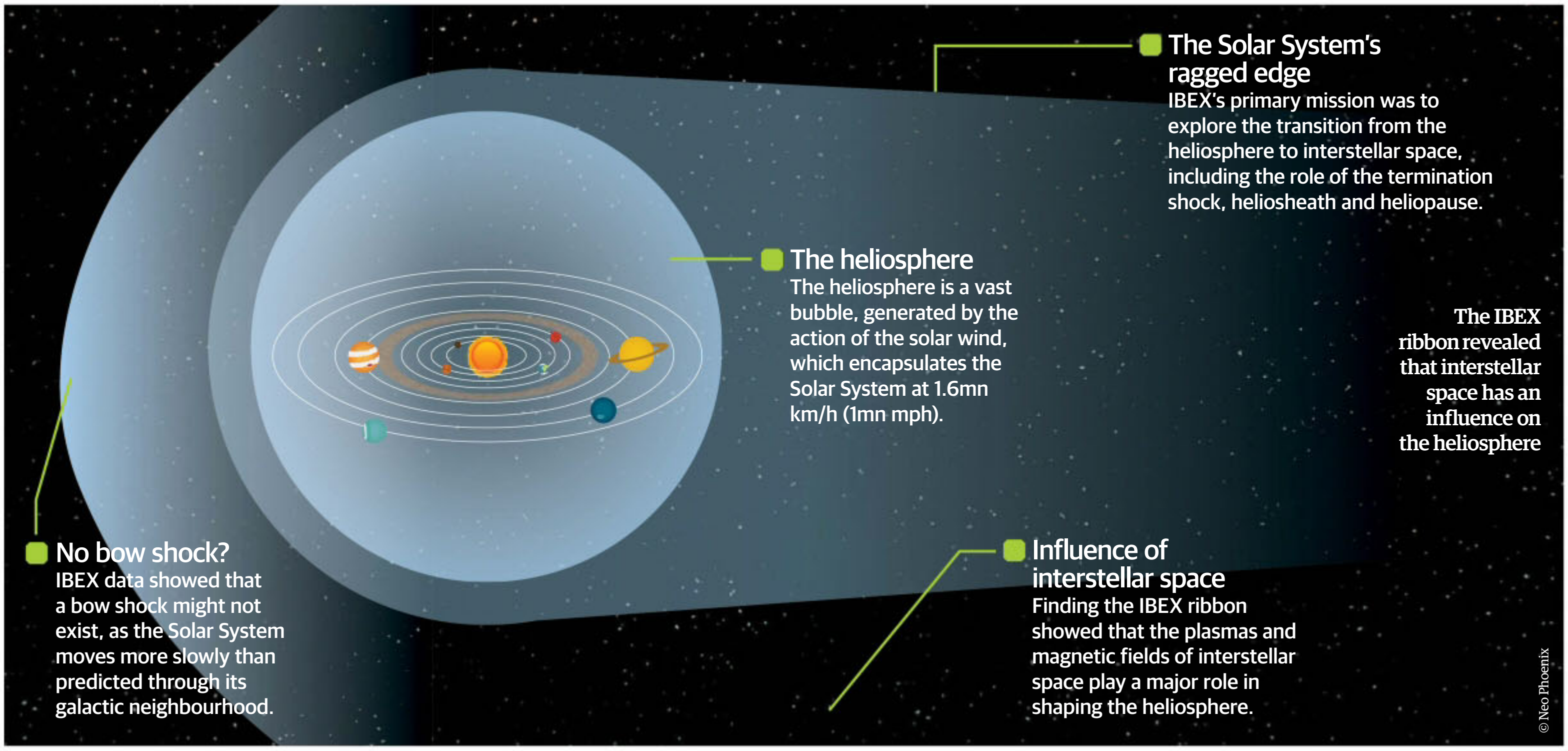
Why galaxies don't wind up

From the Pinwheel to the Andromeda, the universe teems with beautiful spiral galaxies. In our case, the Milky Way rotates every 200 million years, leaving a curious enigma. If these vast conglomerations of stars rotate 'differentially' - those nearest the centre moving faster than those at the periphery - their spiral arms should wind up after a few revolutions, and certainly within a billion years. But our current best guess of the universe's age is 13.8 billion years and some spiral galaxies are almost as old. Following that logic, the average spiral has completed 50 revolutions.

Magnetic fields were one early suggestion for what kept spirals intact. Later, the 'density-wave' theory saw the arms as regions where stars piled up in a fashion akin to a highway at rush hour. Their gravitational attraction prevented the winding problem and maintained the structure of the spiral.

It is possible that shock waves from dying stars could shape the spirals: compressing clouds of gas to stimulate new star birth, thereby keeping the arms visible. However, the processes that form and sustain these spirals remain unclear. In terms of the Whirlpool Galaxy, a nearby companion may be a factor, while computer models counter that spiral arms may be entirely 'transient' features.


We are still unsure as to why the spiral arms of the Milky Way have not yet wound up


The Solar System's ragged edge
IBEX's primary mission was to explore the transition from the heliosphere to interstellar space, including the role of the termination shock, heliosheath and heliopause.

The heliosphere
The heliosphere is a vast bubble, generated by the action of the solar wind, which encapsulates the Solar System at 1.6mn km/h (1mn mph).

The IBEX ribbon revealed that interstellar space has an influence on the heliosphere

No bow shock?
IBEX data showed that a bow shock might not exist, as the Solar System moves more slowly than predicted through its galactic neighbourhood.

Influence of interstellar space
Finding the IBEX ribbon showed that the plasmas and magnetic fields of interstellar space play a major role in shaping the heliosphere.

© Neo Phoenix

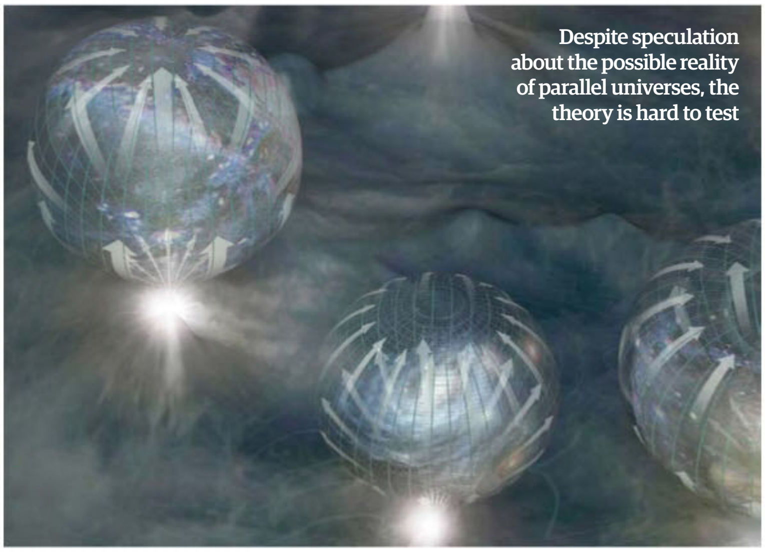
Why there's a ribbon at the edge of our solar neighbourhood

Cocooned within the 'heliosphere' - a vast protective bubble carved by the solar wind, which travels at 1.6 million kilometres (1 million miles) per hour - our Solar System pushes continuously against the plasmas and magnetic fields of interstellar space as it traverses the galaxy. At the front of the heliosphere are the termination shock and heliosheath, where the solar wind slows down and compresses as it interacts with interstellar space.

In 2009, after a year observing this mysterious boundary, the IBEX spacecraft made a startling discovery: a strange 'ribbon' of energetic neutral atoms, twice as bright as anything in the sky. As IBEX studied the ribbon, it found that the structure contorted in response to the direction of the interstellar magnetic field, showing that forces outside the Sun's realm had far greater input into heliospheric dynamics than previously thought.

IBEX uncovered a knot-like feature in the ribbon's northern area and watched as it steadily shrank and seemed to 'untie'. In 2013, it was argued that the ribbon is a 'particle trap' and exists where neutral atoms from the solar wind cross the local galactic magnetic field.

Finding the ribbon carries major implications for space exploration, as the heliosphere shields the Solar System from external radiation. One scientist remarked that IBEX allows us to stick our heads into interstellar space, enabling us to better understand our place in the cosmos.



Despite speculation about the possible reality of parallel universes, the theory is hard to test

A multiverse was discovered

Like the metaphorical monkey sat at a typewriter, tapping out the works of Shakespeare, the idea of parallel universes generating infinite realities alongside our own is an alluring one.

Humanity's sense of aloneness in the cosmos has long been accompanied by a belief that the fabric of the universe cannot be wholly random. This idea has attracted scientific, religious, philosophical and psychological inquiry for decades.

In 2010, data from the Wilkinson Microwave Anisotropy Probe was used to aid arguments that our universe impacted others in the distant past, as evidenced by strange circular patterns in the Cosmic Microwave Background Radiation. These were interpreted as collisional 'bruises'. Subsequent analysis by the Planck spacecraft shed doubt on these claims, revealing no trace for any such event, or any trace of another universe exerting a gravitational pull on our own.

Clearly, parallel universes would exert a powerful influence. Critics claim it is easy to over-interpret random data and difficult to test other realities, as they lie beyond the resolution of our current capabilities. Without rigorous testing, they are less open to scientific scrutiny and must be accepted solely on the grounds of faith.

We found life on Mars

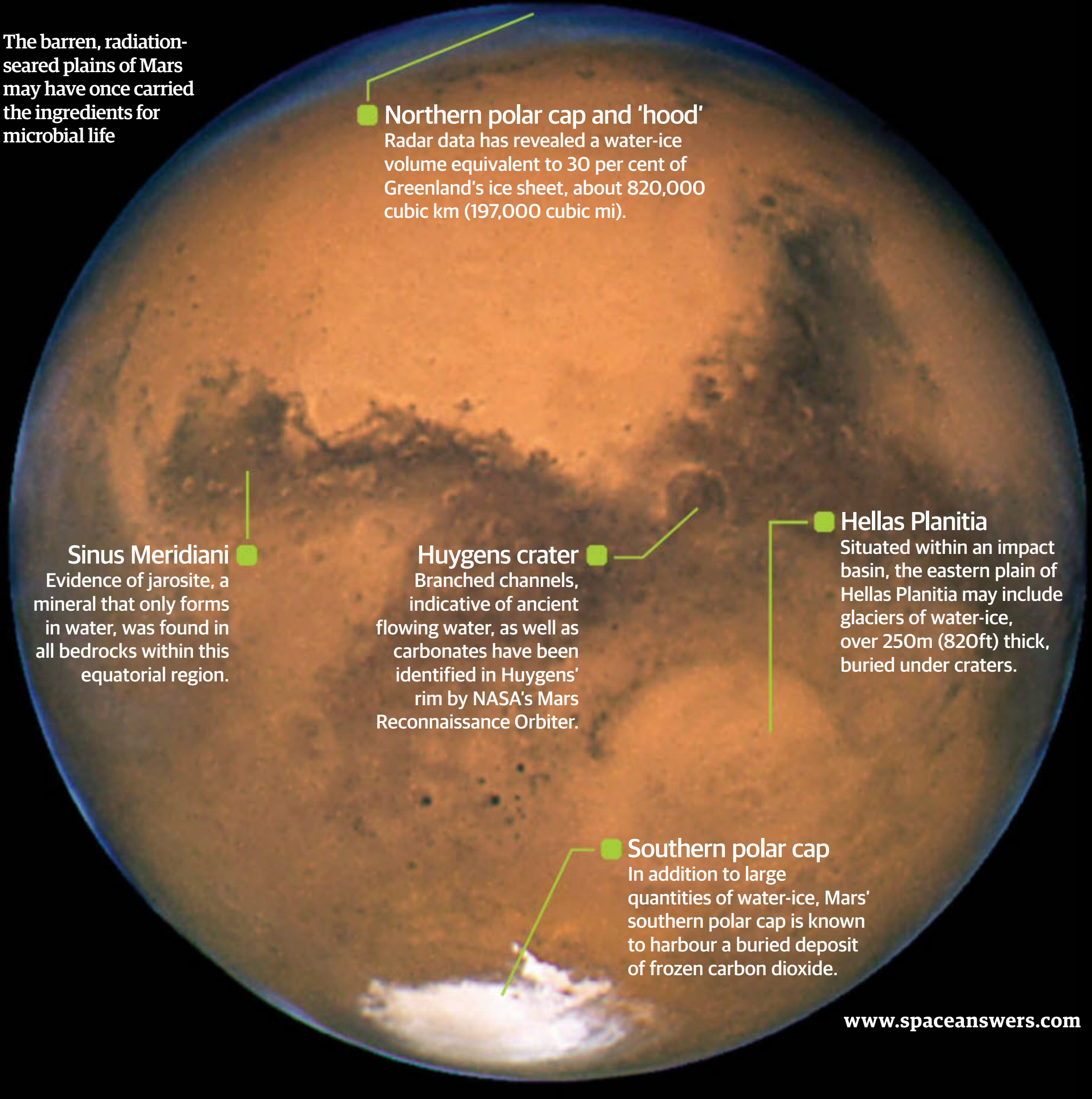
For decades, we have been captivated by the notion of life on Mars. And just as our idea of 'Martians' evolved from monsters to bacteria, our view of the Red Planet swung, pendulum-like, from a habitable world to an inhospitable desert and back. This obsession - from Percival Lowell's imagined canals to the lyrics of David Bowie - underscores a significant mystery. Robotic visitors saw forbidding craters, traces of wind erosion, savage dust storms and evidence of ancient rainfall. Mars revealed candidates for primordial lakes, dried-up river channels and polar water-ice, raising the likelihood that it once harboured life.

Mars' similarity to a young Earth renders it an ideal contender for 'abiogenesis' - a process where life arises naturally from non-living matter. That said, if found, it probably exists in subsurface fluids or sediments. On Earth, 90 per cent of methane is biologically derived, so when NASA's Curiosity rover observed a factor-of-ten jump in methane in 2013, it caused quite a stir. But methane also comes from non-living processes, like the degradation of interplanetary dust by UV light, comet impacts and water-rock interactions.

Yet the mere chance that Mars could support life would irrevocably alter our view of the universe and our place within it. For now, we must content ourselves with the probability that the first 'life' to reach Mars will be ourselves in just a few decades.

Where could life have existed on the Red Planet?

The barren, radiation-seared plains of Mars may have once carried the ingredients for microbial life



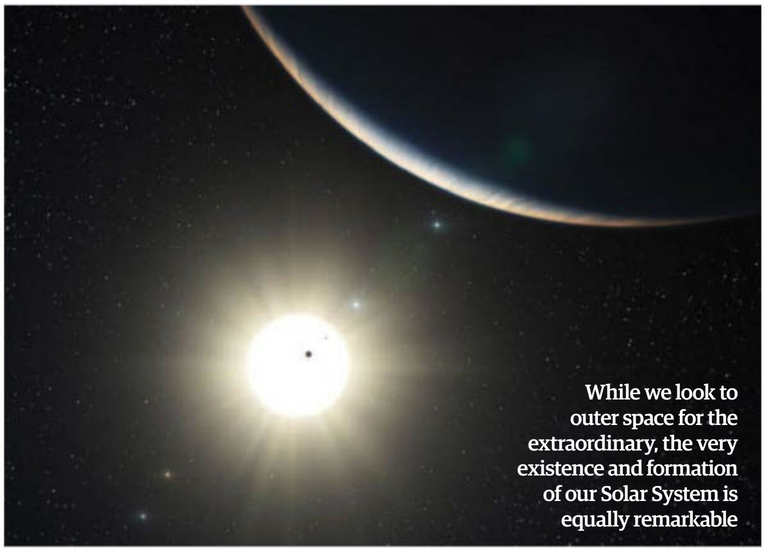
Northern polar cap and 'hood'
Radar data has revealed a water-ice volume equivalent to 30 per cent of Greenland's ice sheet, about 820,000 cubic km (197,000 cubic mi).

Sinus Meridiani
Evidence of jarosite, a mineral that only forms in water, was found in all bedrocks within this equatorial region.

Huygens crater
Branched channels, indicative of ancient flowing water, as well as carbonates have been identified in Huygens' rim by NASA's Mars Reconnaissance Orbiter.

Hellas Planitia
Situated within an impact basin, the eastern plain of Hellas Planitia may include glaciers of water-ice, over 250m (820ft) thick, buried under craters.

Southern polar cap
In addition to large quantities of water-ice, Mars' southern polar cap is known to harbour a buried deposit of frozen carbon dioxide.



While we look to outer space for the extraordinary, the very existence and formation of our Solar System is equally remarkable

Why our Solar System is so strange

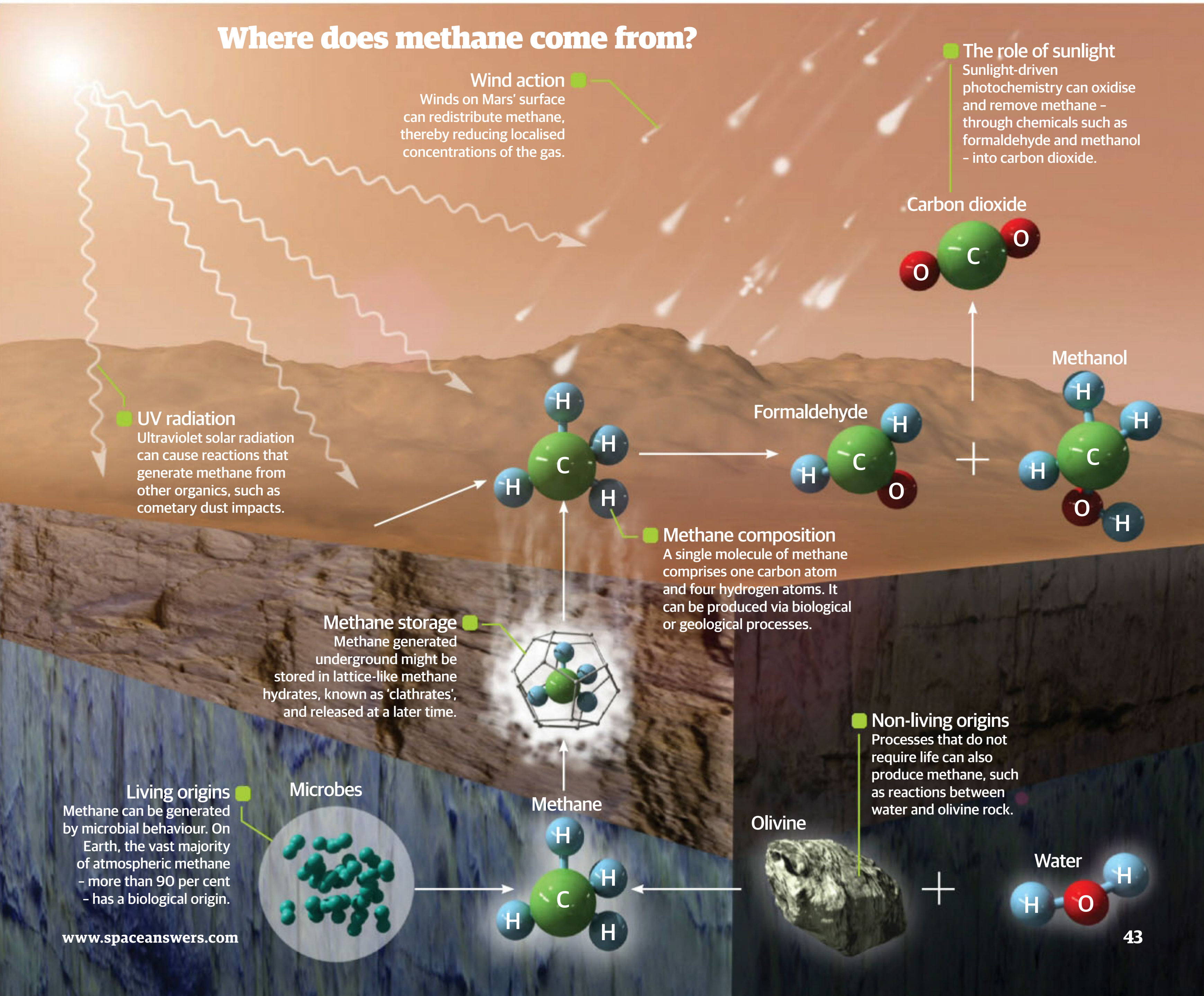
Far along one of the spiral arms of the Milky Way is an ordinary star, surrounded by an unfathomable sea of others. For 4.5 billion years, it progressed unremarkably through its galactic neighbourhood, circled by a rocky, gaseous and icy entourage.

Following the Sun's formation, gas and dust coalesced to form the planets. Some grew larger than others, with heavier elements condensing closer to the Sun and lighter volatiles further away. The result was two 'breeds' of planets: rocky Mercury, Venus, Earth and Mars, and gaseous Jupiter, Saturn, Uranus and Neptune.

Mercury, closest to the Sun, is half-baked and half-frozen, while Venus - so similar to Earth in size - fell victim to a runaway greenhouse effect, which turned it into a searing perversion of paradise. Mars came tantalisingly close to hosting life. Multi-hued Jupiter, larger in size than the rest put together, is followed by beautifully ringed Saturn, the bull's-eye-like Uranus and, finally, Neptune, bearer of the strongest winds in the Solar System.

Yet, remarkably, the strangest fact about our unusual Solar System is found right here on Earth; this insignificant speck in a corner of the Milky Way is the only place in the universe where we know that life definitely evolved.

Where does methane come from?



Wind action
Winds on Mars' surface can redistribute methane, thereby reducing localised concentrations of the gas.

The role of sunlight
Sunlight-driven photochemistry can oxidise and remove methane – through chemicals such as formaldehyde and methanol – into carbon dioxide.

UV radiation
Ultraviolet solar radiation can cause reactions that generate methane from other organics, such as cometary dust impacts.

Methane composition
A single molecule of methane comprises one carbon atom and four hydrogen atoms. It can be produced via biological or geological processes.

Methane storage
Methane generated underground might be stored in lattice-like methane hydrates, known as 'clathrates', and released at a later time.

Non-living origins
Processes that do not require life can also produce methane, such as reactions between water and olivine rock.

Living origins
Methane can be generated by microbial behaviour. On Earth, the vast majority of atmospheric methane – more than 90 per cent – has a biological origin.

The search for extraterrestrial life is ongoing

We made contact with an alien civilisation

In Hollywood, aliens have contacted us many times, and our reaction to the arrival of extraterrestrials illustrates our uncertainty about their form and their motives. Countless millennia of invasion and warfare, plus decades of UFO and conspiracy folklore, have left an ingrained fear of aliens.

If contact does occur, it will be in one of two ways: either a sudden event or a gradual awareness from the accumulation of evidence. At present, with clues to water on Mars and the detection of potentially habitable exoplanets, we seem to be heading down the second path.

But if 'first contact' did come as a single event, like a flying saucer landing on the White House lawn, the consequences would be profound. Cosmologist Carl Sagan believed that a civilisation with the ability to reach Earth would have transcended war, but it is impossible to know for sure.

There's no certainty that we could understand extraterrestrials, and the impact on our culture, religion and philosophy is impossible to fathom. The question of whether or not we are alone in the universe remains. Both possibilities, writer Arthur C Clarke famously said, are equally terrifying.

Where life on Earth came from

Five centuries ago, even the most educated civilisations believed that the Earth lay at the centre of the universe. Just as that stance was common back then, so modern thinking remains very 'Earth-centric' with respect to the origins of life.

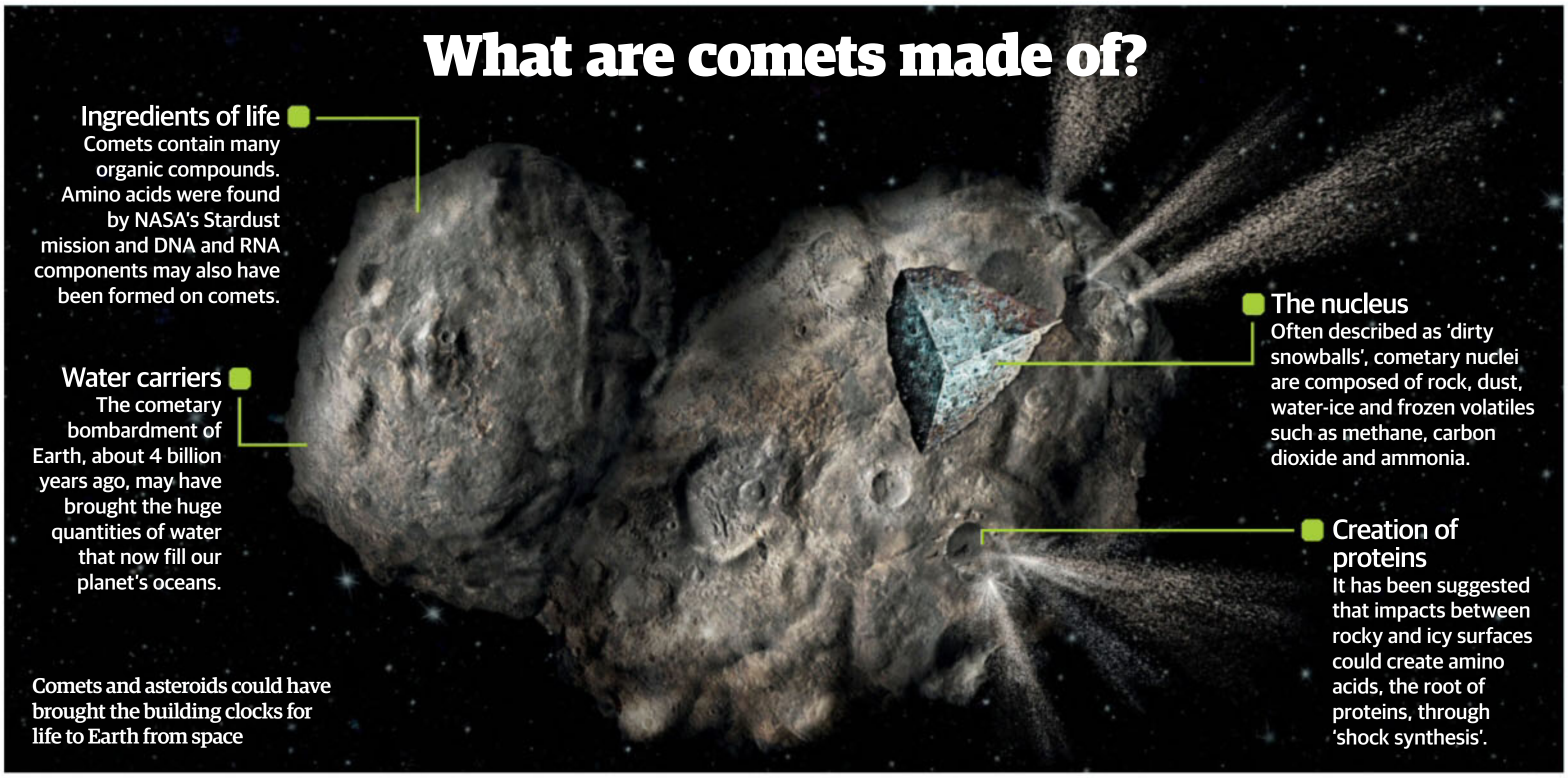
But when Europe's Rosetta orbiter and Philae lander reached Comet 67P/Churyumov-Gerasimenko in 2014, they found significant outgassing of molecular oxygen, as well as many organic compounds inside its darkened crust. It has long been theorised that these icy relics of the ancient Solar System – laden with volatiles like carbon monoxide, ammonia and water-ice from outer space – may have sown the seeds for life on Earth, through 'panspermia'.

Life on Earth began around 3.8 billion years ago, with general consensus favouring self-replicating RNA genetic molecules. This was only a few hundred million years after our planet's formation, and this rapid appearance of life might be common throughout the universe.

In its youth, Earth had relatively little water or carbon-based constituents, but our home planet was heavily bombarded by comets and asteroids. It is possible that huge amounts of water and carbon-based molecules arrived on the Earth via these impactors.

Certainly, NASA's Stardust mission found traces of amino acids in Comet Wild 2 and the Deep Impact spacecraft detected organic and clay particles inside Comet Tempel 1, showing that these space objects do host some of the organic compounds needed for life. If comets and asteroids did indeed bring some of the building blocks for life to Earth from outer space, could they have also done so elsewhere in the universe?

What are comets made of?



Ingredients of life
Comets contain many organic compounds. Amino acids were found by NASA's Stardust mission and DNA and RNA components may also have been formed on comets.

Water carriers
The cometary bombardment of Earth, about 4 billion years ago, may have brought the huge quantities of water that now fill our planet's oceans.

The nucleus
Often described as 'dirty snowballs', cometary nuclei are composed of rock, dust, water-ice and frozen volatiles such as methane, carbon dioxide and ammonia.

Creation of proteins
It has been suggested that impacts between rocky and icy surfaces could create amino acids, the root of proteins, through 'shock synthesis'.

Comets and asteroids could have brought the building clocks for life to Earth from space

Where the other part of the universe went

When the universe came into existence 13.8 billion years ago, equal quantities of matter and antimatter should have been created. Their particles were generated in pairs and annihilated each other on contact, which released pure energy in the form of gamma radiation. In the first instant after the Big Bang, positively charged particles and negatively charged antiparticles were both created and destroyed.

Although enough matter survived to generate today's observable galaxies, there is little evidence of antimatter in the universe. Where it went - the puzzle of 'baryogenesis' - is one of the greatest challenges of modern particle physics. Existing models and Einstein's general theory of relatively both fail to offer a satisfactory explanation.

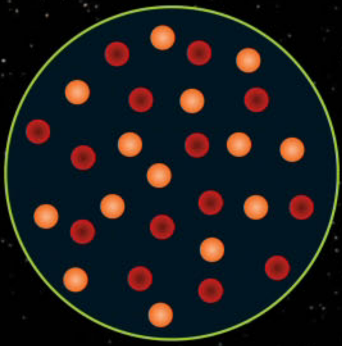
A violation of charge-particle symmetry, which states that the laws of physics should stay the same if a particle is exchanged for an antiparticle, is an explanation for where the antimatter went. At present, there are two leading interpretations for the disparity.

One argues that the Big Bang left a tiny preference for matter, while the second theorises that the universe was perfectly symmetrical at birth, but later experienced a small imbalance in favour of matter.

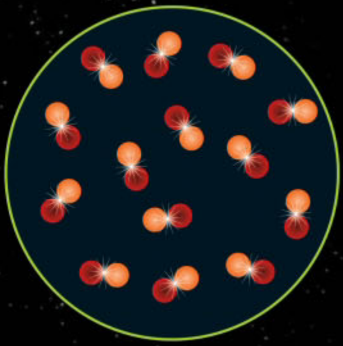
However, no clear observational evidence exists to validate either theory and explanations for the disparity remain scarce.

Where did the antimatter go?

The universe comes into being
It is generally believed that the universe was born in the Big Bang, a rapidly expanding fireball of extremely intense energy.



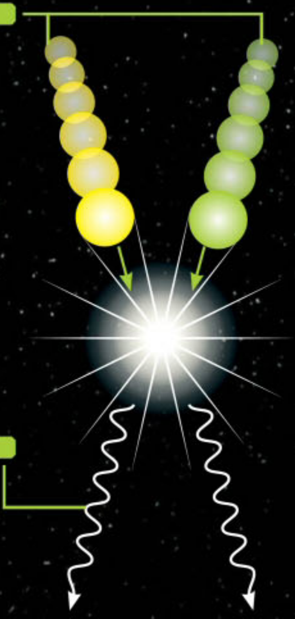
Matter and antimatter are created
Immediately after the Big Bang, the universe should have contained equal amounts of matter and antimatter.



Matter-antimatter annihilation
In theory, matter and antimatter particles and antiparticles should have annihilated each other, releasing pure energy in the form of gamma radiation.

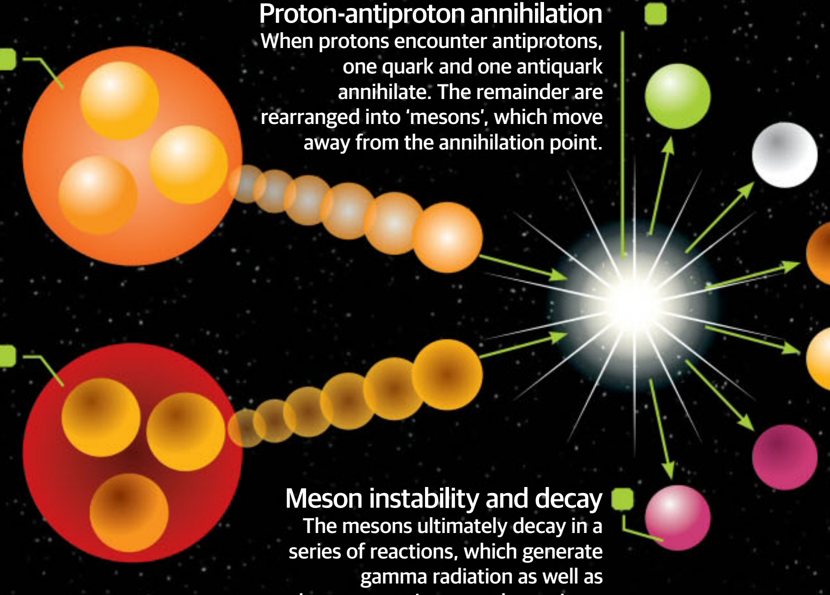
Missing antimatter
Although sufficient matter remained to form the observable galaxies in the universe, very little antimatter can be found. Where it went is still a mystery.

Matter-antimatter annihilation



Positron-electron collisions
Positively charged and negatively charged particles collide at the dawn of time, annihilating each other on contact.

Production of pure energy
The positron-electron collision generates pure energy in the form of gamma radiation.



Constituents of protons
A proton is a positively charged subatomic particle, consisting of two 'up quarks' and one 'down quark'.

Constituents of antiprotons
An antiproton is a negatively charged subatomic particle, with two 'up antiquarks' and one 'down antiquark'.

Proton-antiproton annihilation
When protons encounter antiprotons, one quark and one antiquark annihilate. The remainder are rearranged into 'mesons', which move away from the annihilation point.

Meson instability and decay
The mesons ultimately decay in a series of reactions, which generate gamma radiation as well as electrons, positrons and neutrinos.

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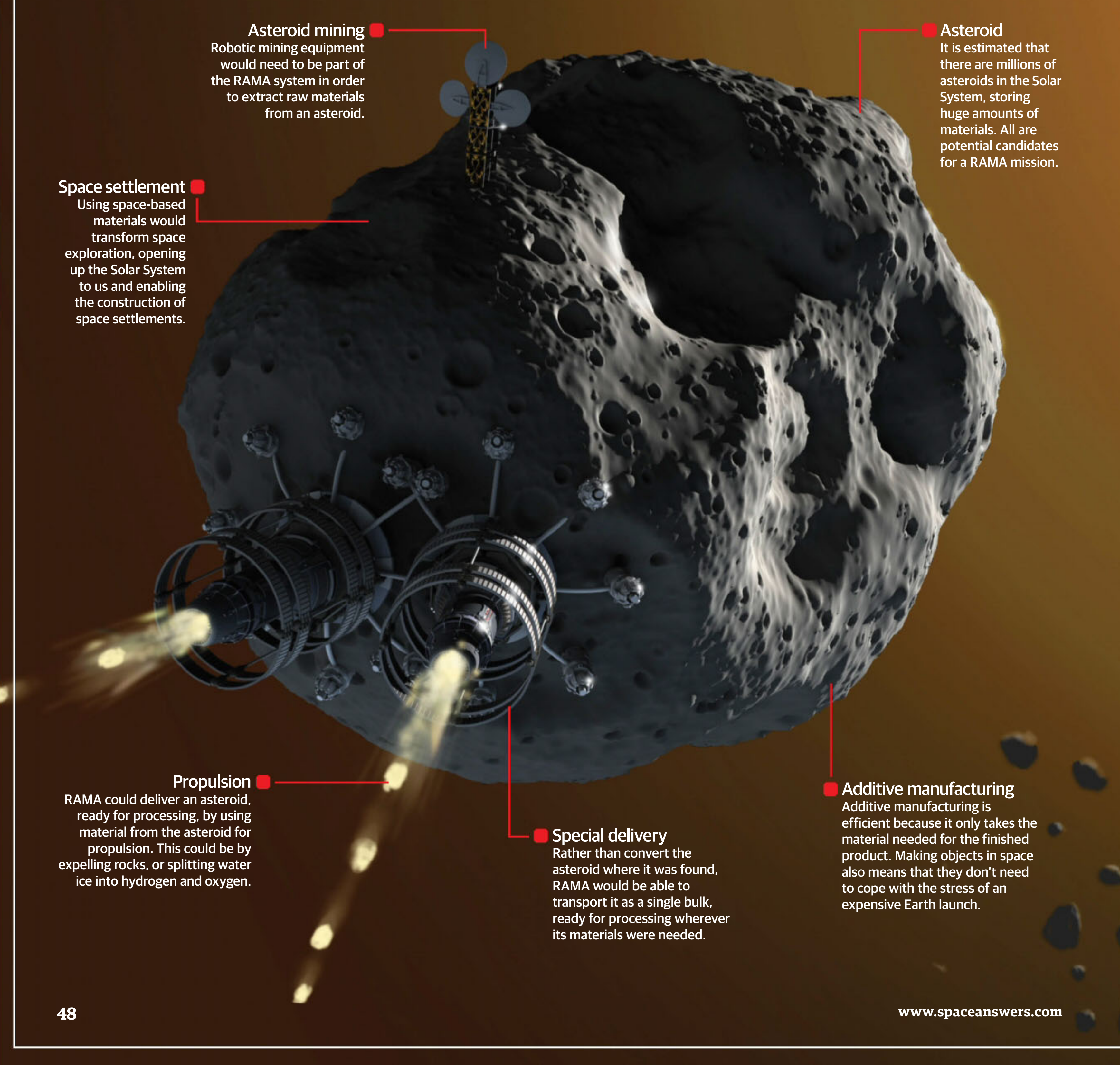
Project RAMA

A Californian company wants to turn asteroids into autonomous spacecraft - to mine them and to relocate them in space



Asteroid mining
Robotic mining equipment would need to be part of the RAMA system in order to extract raw materials from an asteroid.

Asteroid
It is estimated that there are millions of asteroids in the Solar System, storing huge amounts of materials. All are potential candidates for a RAMA mission.

Space settlement
Using space-based materials would transform space exploration, opening up the Solar System to us and enabling the construction of space settlements.

Propulsion
RAMA could deliver an asteroid, ready for processing, by using material from the asteroid for propulsion. This could be by expelling rocks, or splitting water ice into hydrogen and oxygen.

Special delivery
Rather than convert the asteroid where it was found, RAMA would be able to transport it as a single bulk, ready for processing wherever its materials were needed.

Additive manufacturing
Additive manufacturing is efficient because it only takes the material needed for the finished product. Making objects in space also means that they don't need to cope with the stress of an expensive Earth launch.

Power supply
Little engineering detail has emerged as yet, but it is likely that inner Solar System RAMAs would use solar power. From Mars outwards, they would use nuclear power.

Hazardous asteroids
Asteroid impacts have happened before and are likely to happen again unless we can deflect them. RAMA would be able to do this, gently using the asteroid's own resources to change its orbit.

© Adrian Mann

> "A RAMA mission could be sent to a potentially Earth-crossing asteroid to push it off course and collect it for its resources – the ultimate Earth revenge!"

Every year NASA selects a range of speculative projects through its Innovative Advanced Concepts (NIAC) programme, and this year space 3D printing specialist, Made In Space (MIS), has received an award for Project RAMA. The project is partly named after an Arthur C Clarke story where an empty, automated colony ship built in an asteroid arrives in the Solar System; the initials in this case stand for Reconstituting Asteroids into Mechanical Automata.

Based in Mountain View, California, MIS was founded in 2010 with the aim of using additive manufacturing (3D printing) to dramatically reduce the costs of operations in space. In additive manufacturing a supply material, often a plastic filament or metal dust, is fused together into objects rather than cut out of a bigger piece. For launch from Earth this would save volume and mass and space missions would be able to print spare parts as needed. MIS recently supplied a printer to the ISS in order to test the process in microgravity.

But MIS's ultimate goal, which would enable mass settlement in space, is to employ additive manufacturing with materials sourced in space; and this is where RAMA comes in. Not only would it save the cost and difficulty of launching stuff from Earth (we'd only need to send people and their luggage), but there are far more resources available up there.

The RAMA concept will likely consist of a whole range of technologies that could be deposited on an asteroid, where they could extract raw materials, process them into usable forms and pass them on. These materials could then be used for additive manufacturing to build things, possibly even bigger versions of the extraction and manufacturing systems, so a small initial lander could build up an asteroid-scale installation out of the asteroid itself.

RAMA's other main system will be propulsion, which will use material from the asteroid as a reactive mass. In its most basic form, this could mean firing rubble off the surface with an electromagnetic catapult. Better performance could be gained if the asteroid could provide water or hydrocarbons that could be used in a conventional rocket engine. Once a RAMA installation was in place on the asteroid then it could be moved en-masse to wherever in the Solar System its resources were needed: a self-contained and propelled mine and factory in one.

It only takes a small change in speed to gradually change the orbit of an asteroid so, as well as delivering resources, RAMA may be useful for Earth defence. Astronomers are making increasing efforts to track and record the orbits of potentially Earth-crossing asteroids. When a candidate is found, its orbit is analysed so that the uncertainty of its future path is reduced until we can be sure if it will miss the Earth or not. Because of the consistency of orbits we should know several years, even decades, in advance. In which case, a RAMA mission could be sent to the offending asteroid to push it off course and collect it for its resources – the ultimate Earth revenge!

Although NIAC projects are not expected to deliver immediate results, RAMA does build on technologies that are already maturing; now it's just a question of scale. If they are able to do it, MIS could become one of humanity's most significant companies; making huge profits, while enabling space settlement and protecting Earth from asteroid impacts.

An interview with Elon Musk

Not content with having the only private company to return a spacecraft from low-Earth orbit, the CEO of SpaceX is aiming for the Red Planet by 2018

Interviewed by David Crookes

There is a feeling that Elon Musk is on a perpetual upward trajectory, his ambition soaring skyward, closely followed by the technical know-how of how he can achieve his myriad aims. He is only 44 years old but each line of his CV reads like a lifelong career goal. He is making his way through the most ambitious checklist ever written: cofound PayPal, set up Tesla Motors, create SpaceX and change the world. Tick, tick, tick and tick.

Of course, of these feats, the founding of SpaceX is the one that sticks out the most. It was created to satiate Musk's overwhelming desire to put people on Mars and it captures the imagination like a meteorite hunter grabs at rocks. Everything Musk does at SpaceX is with a journey to the Red Planet in mind. "The goal of SpaceX is to try to advance rocket technology and, in particular, to try to crack a problem that I think is vital for humanity to become a space-faring civilisation, which is to have a rapidly and fully reusable rocket," he says.

For him, the worst thing that could happen is that humans are forever confined to Earth. "What are the important steps in the evolution of life?" Musk asks rhetorically, before cycling through various key moments from the single-celled organism, to differentiation of plants and animals, to life moving from the ocean to land, and the development of consciousness. The next step, he says, is for some humans to leave Earth. "I would argue on that scale, life should become multi-planetary," says Musk.

He wants to allow humans to move away from being a single-planet species to one that is able to live elsewhere in the universe. "If life as we know it is multi-planetary then the probable length of existence of human civilisation is much greater," he says, nodding to the alternative of sticking around on Earth until the end of our days and then fizzling out for a lack of anywhere else to go.

SpaceX CRS-5 was a successful cargo re-supply mission to the ISS, shown here in orbit

"There are two main motivations for Mars," he continues. "One is the defensive reason: if something were to happen to Earth, would life as we know it end? If it's on another planet then it probably doesn't end. Multi-planet civilisation is likely to last longer than a single-planet civilisation." And the second motivation? "It would also just be an incredible adventure and very exciting," adds Musk.

And how has he done this? "Well, we've made significant advances in the technology of the airframe, the engines, the electronics and the launch operation. There's a long list of innovations that we've come up with," explains Musk, keeping the details behind closed doors for now.

Musk is not alone in his thinking. NASA's focus on Mars has colonisation as an ultimate goal, again, to secure the future of humankind, but also to better understand other planets. Yet it knows better than anyone the trials and tribulations of achieving such an aim. The Curiosity rover is currently trundling over Mars and the rugged terrain has thrown up myriad problems along the way – the latest being the toll felt on the rover's six wheels. But that isn't going to stop its scientists in their tracks. NASA is preparing to put a 1.8-metre (six-foot) tall, 125-kilogram (275-pound) humanoid called Valkyrie into space. It's being taught new commands and skills that should equip it for deeper space explorations.

SpaceX has had its setbacks too, but Musk keeps going. The company works closely with NASA and indeed, in April it won the first US tender in ten years to launch military satellites, putting an end to the monopoly long enjoyed by Boeing and Lockheed Martin. But Musk has a sense of wanting to do things his way, too. His biggest reveal of recent times was that he wants to send a SpaceX Dragon 2 spaceship to Mars by 2018 using Falcon Heavy rockets. "It's important to have things that inspire us," he says of his motivation to work on this programme. "It can't always be solving miserable problems all of the time, otherwise why get up in the morning?"

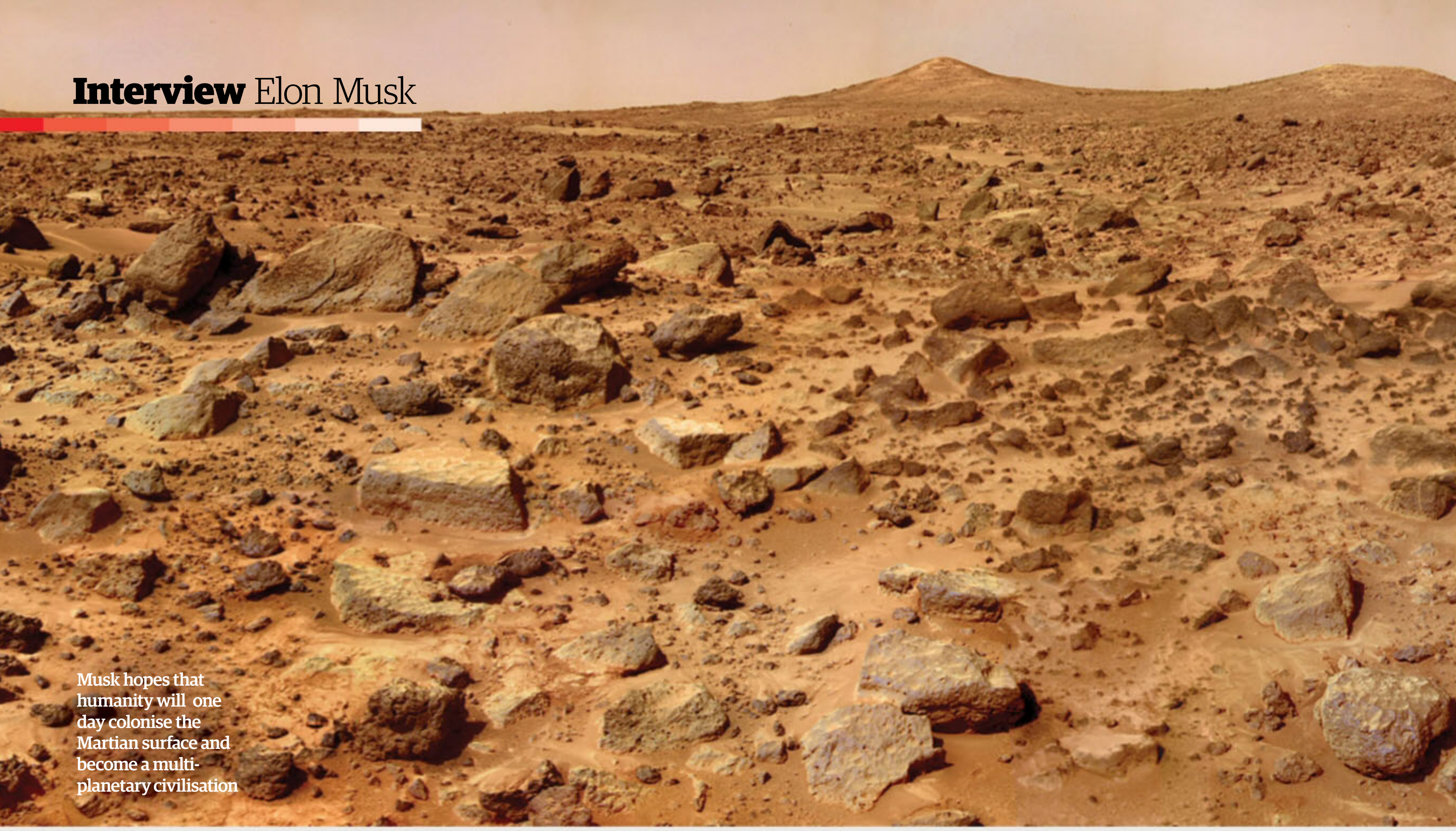
The announcement of the 2018 proposal came in a Tweet from SpaceX: "Planning to send Dragon to Mars as soon as 2018. Red Dragons will inform

“SpaceX will head to Mars by 2018”

INTERVIEW BIO

Elon Musk

Elon Musk is the founder of the private aerospace company SpaceX, which designs, manufactures and launches advanced reusable rockets and spacecraft. Having already sent cargo to the International Space Station via its Falcon 9 rocket and Dragon spacecraft, his company continues to work on technology that will one day allow humans to venture to Mars and establish a huge colony, helping to secure the future of our species.



Musk hopes that humanity will one day colonise the Martian surface and become a multi-planetary civilisation

SpaceX sent its Dragon cargo spacecraft to the ISS in May 2012 and here the space station's six crew members take an opportunity to climb inside

SpaceX's Falcon 9 first stage successfully performs several engine burns and goes on to land vertically on a drone ship off the coast of Florida on 6 May 2016

"I think it is vital for humanity to become a space-faring civilisation. Life should become multi-planetary"

overall Mars architecture, details to come." But Musk has long hinted this would be the case; only the date was a surprise. In 2015 he told an 'Ask Me Anything' session on Reddit: "Dragon V2 is designed to be able to land anywhere in the Solar System. Red Dragon Mars mission is the first test flight." And yet there is still so much to work on.

For a start, because the interior of the capsule is tight, it wouldn't be ready to carry people just yet. "I wouldn't recommend transporting astronauts beyond the Earth-Moon region," Musk continues. "[It] wouldn't be fun for longer journeys [because it has the] internal volume size of an SUV." Eventually though, he wants to see 80,000 people colonising Mars. He said this at the Royal Aeronautical Society back in 2012 and he doesn't seem to be looking to water down the numbers. You can't fault the ambition. And that year, SpaceX became the first private US company to deliver cargo to the International Space Station (ISS), despite being a relatively new start-up at the time.

An important aspect to travel at SpaceX is that the rockets are, in theory at least, reusable. "All rockets that fly today are fully expendable," he explains. "The Space Shuttle was an attempt at a reusable rocket, but even the main tank of the Space Shuttle was thrown away every time, and the parts that were reusable took a 10,000-person group nine months to refurbish for flight. So the Space Shuttle ended up costing a billion dollars [£680.4 million] per flight. Obviously that doesn't work very well."

Instead, Musk has often referred to the Mars Colonial Transporter (MCT), the project that is looking to build a viable spacecraft that includes the human-carrying capsules, launch vehicles and reusable rocket engines. It'll be operational sometime after the mid-2020s but there is still a lot of mystery surrounding what it will actually be like in reality. "The Mars transport system will be a completely new architecture," Musk offers vaguely, saying the team learned a huge amount from the development of Falcon and Dragon.

Whatever happens, it will have to be big if he wants to get 100 passengers at a time up there. "The goal is 100 metric tonnes of useful payload to the surface of Mars. This obviously requires a very big spaceship and booster system," says Musk. As for the spacesuits humans would need to wear, both as they travel to Mars and when they finally step foot on the hallowed surface, he adds: "Our spacesuit design is finally coming together and will also be unveiled later this year. We are putting a lot of effort into design aesthetics, not just utility. It needs to both look like a 21st century spacesuit and work well. [It's] really difficult to achieve both."

Design, it seems, is important to Musk and that is only underlined by the news in May this year that Jose Fernandez, a costume designer who has worked on many superhero suits for Hollywood comic book movies, has been working on SpaceX's new clobber. "They are going to reveal it in the next year," Fernandez says. "They are going to be wearing these to space and that's cool."

Whether or not SpaceX will be able to make them for much less than the $180,000 (£123,000) that it currently costs NASA to produce Intra-Vehicular

Activity suits is another matter. Musk is presumably hoping they will cost less than the $12 million (£8.2 million) Extra-Vehicular Activity equivalents, and it's likely he will be aiming to produce suits that can be used more than once, just like the company's rockets.

Musk wants the MCT launch vehicle to be used over and over again, which would reduce the cost of space travel and allow more people to go to Mars. But if that is to happen, then it needs to be even bigger and better than the Falcon Heavy rocket, which is nonrecoverable as it stands. "Actually, we could make the second stage of Falcon reusable and still have significant payload on Falcon Heavy," he says, "but I think our engineering resources are better spent moving on to the Mars system. MCT will have meaningfully higher specific impulse engines: 380 vs 345 vac Isp. For those unfamiliar, in the rocket world, that is a super gigantic difference."

Efforts have been concentrated on Falcon 9, which has steerable fins that allows it to be guided to a landing platform, recovered and used again. "The grid fins are super important for landing with precision," Musk says. "The aerodynamic forces are way too strong for the nitrogen thrusters. In particular, achieving pitch trim is hopeless. Our atmosphere is like molasses at Mach 4!"

This was seen in action on 6 May this year, when SpaceX showed its growing experience in this area. Falcon 9 launched the Japanese satellite JCSAT-14, aimed at providing television and data services across the Pacific. Once this had been done, the first stage of the rocket was then landed on a floating platform off the coast of Florida called Of Course I Still Love You, the second time the company has been able to do this while keeping the rocket intact.

Beforehand, Musk wasn't entirely confident it would work: "Rocket re-entry is a lot faster and hotter than last time, so the odds of making it are maybe even, but we should learn a lot either way." But when the rocket landed successfully his response was simple and to the point. "Woohoo," he says, before adding, "We may need to increase the size of the rocket storage hanger," a joking reference to the capacity at Launch Complex 39A, a spaceport in Cape Canaveral that can hold five vehicles.

It was certainly a feat of engineering, with a three-engine landing burning at "triple deceleration of the last flight," which is important to "minimise gravity losses." It was secured to the barge through "mostly gravity." Musk explains, "The centre of gravity is pretty low for the booster, as all of the engines and residual propellant are at the bottom, so we are going to weld steel shoes over the landing feet as a precautionary measure."

All of this is good news for SpaceX. Where rivals may charge $164 million (£112 million) for a launch, SpaceX says it can do the same for $40 million (£27 million). In the long-term this allows SpaceX to become an attractive company to deal with, bringing it more money and more resources in order to achieve its aim for Mars colonisation. It's inspirational stuff from the man who was nicknamed 'genius boy' as a child and was bullied by his peers, and it is also something that is likely to give him the last laugh. After all, who knows, maybe one day those who derided him will be watching him set foot on Mars. With Musk, you sense that anything could happen.

Crew Dragon is SpaceX's spacecraft intended for taking humans to the ISS and beyond

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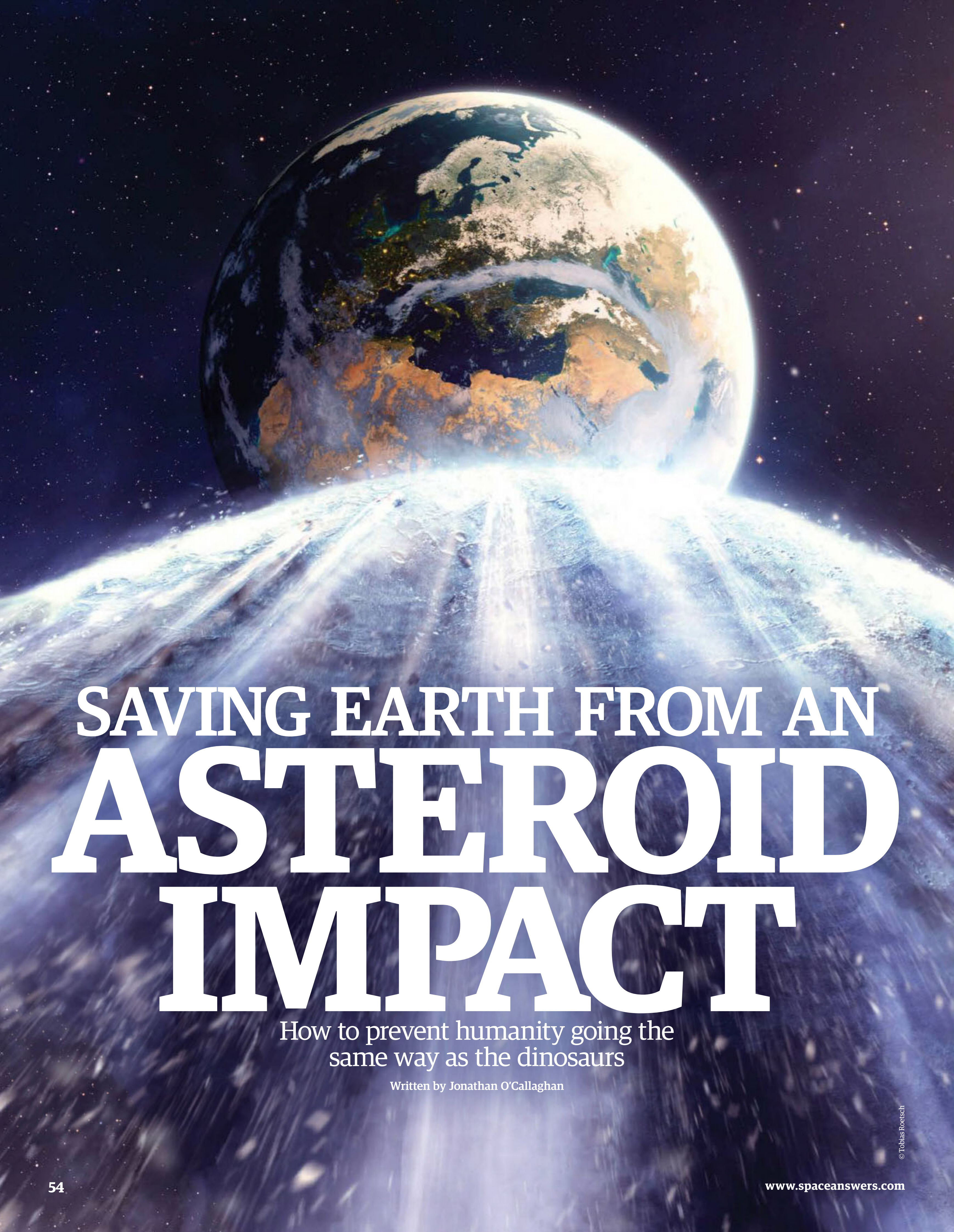
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SAVING EARTH FROM AN ASTEROID IMPACT

How to prevent humanity going the same way as the dinosaurs

Written by Jonathan O'Callaghan

For most experts, it is a question of when, not if, Earth is struck by a killer asteroid. When it happened 66 million years ago, the dinosaurs were wiped off the face of the planet. So how do we stop the same fate befalling humanity?

That's a question that is being discussed around the world as we speak. A number of missions and proposals are looking at how we can better track asteroids, to ensure that if we do find ourselves in the line of fire, we can do something about it. The only problem is, it's not so easy to convince people to do so. An asteroid impact is a very real threat, but unlike things like climate change or earthquakes, it's not very tangible. We very rarely see asteroids cause any devastation; the Chelyabinsk meteor in February 2013 was probably the most notable in recent memory, but we haven't exactly been rushing to stop a repeat performance since then.

Raising awareness about asteroids is the key goal for German filmmaker Grigorij Richters. In 2014, he started a movement called Asteroid Day, which aims to bring the threat of asteroids into the public eye once a year. This year Asteroid Day will be held on June 30 - which is the date an asteroid exploded over Tunguska in Siberia in 1908, flattening 2,000 square kilometres (770 square miles) of forest, and which is probably the biggest impact in recent history. Had the Tunguska asteroid hit Earth just a few hours earlier, a city such as London could have been devastated.

"Asteroids are one of those threats we can do something about, that's the key message," Richters tells **All About Space**. "It's not a hopeless game of cat and mouse. We, the human species, have the brains and the tools to solve this issue. As a scientist once said to me, it's not rocket science."

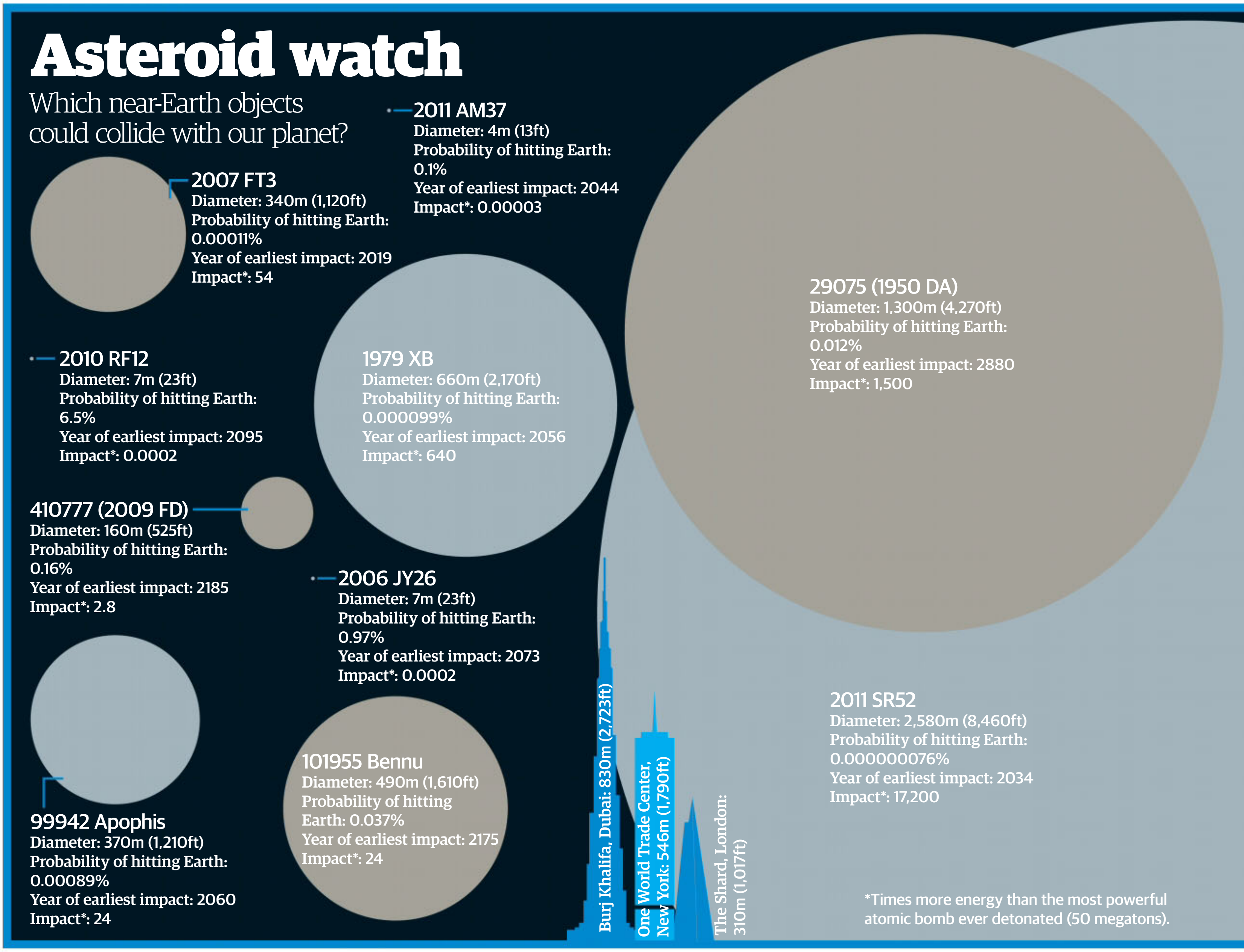
Asteroid Day will see more than 600 events take place around the world to raise awareness about asteroids, with many free events taking place in museums and public spaces. Among its supporters are some famous names including astrophysicist (and Queen guitarist) Brian May, and British Astronomer Royal, Lord Martin Rees. But what can we actually do? After all, some asteroids can be as large as entire cities. Do we have any hope of stopping one if it's on its way to Earth?

Well, the first thing we can do is to get better at tracking asteroids. At the moment, there are only a handful of organisations around the world that are tasked with gazing at the night sky and looking

> "Due to the incompleteness of our near-Earth object catalogue, an unexpected impact could occur any day"

Asteroid watch

Which near-Earth objects could collide with our planet?



2011 AM37
Diameter: 4m (13ft)
Probability of hitting Earth: 0.1%
Year of earliest impact: 2044
Impact*: 0.00003

2007 FT3
Diameter: 340m (1,120ft)
Probability of hitting Earth: 0.00011%
Year of earliest impact: 2019
Impact*: 54

29075 (1950 DA)
Diameter: 1,300m (4,270ft)
Probability of hitting Earth: 0.012%
Year of earliest impact: 2880
Impact*: 1,500

2010 RF12
Diameter: 7m (23ft)
Probability of hitting Earth: 6.5%
Year of earliest impact: 2095
Impact*: 0.0002

1979 XB
Diameter: 660m (2,170ft)
Probability of hitting Earth: 0.000099%
Year of earliest impact: 2056
Impact*: 640

410777 (2009 FD)
Diameter: 160m (525ft)
Probability of hitting Earth: 0.16%
Year of earliest impact: 2185
Impact*: 2.8

2006 JY26
Diameter: 7m (23ft)
Probability of hitting Earth: 0.97%
Year of earliest impact: 2073
Impact*: 0.0002

2011 SR52
Diameter: 2,580m (8,460ft)
Probability of hitting Earth: 0.000000076%
Year of earliest impact: 2034
Impact*: 17,200

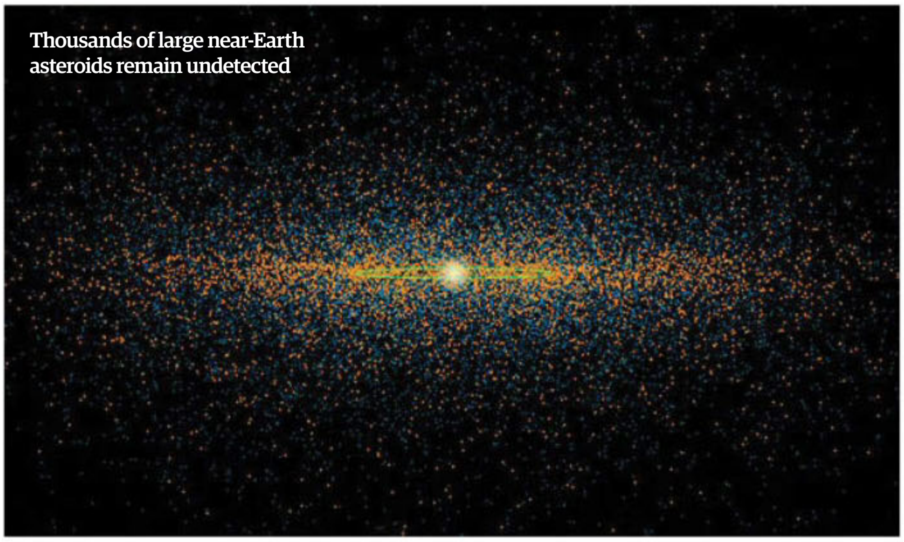
101955 Bennu
Diameter: 490m (1,610ft)
Probability of hitting Earth: 0.037%
Year of earliest impact: 2175
Impact*: 24

99942 Apophis
Diameter: 370m (1,210ft)
Probability of hitting Earth: 0.00089%
Year of earliest impact: 2060
Impact*: 24

*Times more energy than the most powerful atomic bomb ever detonated (50 megatons).

We don't know a huge amount about what asteroids are made of yet

The AIDA mission will attempt to change an asteroid's trajectory in 2022



Thousands of large near-Earth asteroids remain undetected

for asteroids and comets. One of those is NASA's Planetary Defense Coordination Office, which aims to track all near-Earth objects (NEOs) and potentially hazardous objects (PHOs) that are larger than 30 metres (100 feet) and could pose a threat to Earth, using an array of telescopes and observatories around the world.

"NASA-sponsored efforts have discovered almost 14,000 NEOs since 1998 when NASA began tracking and cataloguing NEO discoveries," says Lindley Johnson, NASA's Planetary Defense Officer. "Over the past two years, we have discovered more than 1,500 previously unknown NEOs each year."

While that might sound good, don't be too impressed. Based on population estimates, 74 per cent of NEOs larger than 140 metres (460 feet) have not yet been discovered. Johnson says that to detect these additional objects, we need to launch a dedicated space-based infrared asteroid survey telescope, something that's not currently on the table. Our best asteroid hunter at the moment is the NEOWISE (Near-Earth Object Wide-field Infrared Survey Explorer) telescope, but it's not quite up to the task. Initiatives like Asteroid Day seek to bring issues like this to the public's attention, to drum up support for future missions.

Fortunately, at the moment, we don't actually know of any asteroids that pose an imminent danger to Earth. Asteroid 2009 FD is currently the highest risk for an impact from a sizeable asteroid, which has a one in 714 chance of hitting us in 2185. But that's not to say there isn't something else out there.

"Asteroid impacts are a continuously occurring natural process," said Johnson. "Every day, about 80 to 100 tons of material falls upon Earth from space in the form of dust and smaller meteoroids. An impact like the one over Chelyabinsk in 2013 is estimated to take place once or twice a century, and impacts of larger objects are expected to be far less frequent, on the scale of centuries to millennia. However, given the current incompleteness of our NEO catalogue, an unexpected impact could occur any day."

So, if and when we do find an asteroid with our name on it, what can we do? Well, for this, there are a number of proposals on the table. Don't get your hopes up for a Bruce Willis-type character to be planting explosives, though. Instead, it's more likely that we would aim to change the orbit of an asteroid ever so slightly, many years in advance of it hitting us, to ensure it misses. With a few decades warning, we'd only need to change an asteroid's velocity by about 2.5 centimetres (one inch) per second to divert it away from Earth. To test out how we'd do this, NASA and ESA are currently working on the joint

> "This will be the first time in human history that we have actually changed the orbital characteristics of a body in the Solar System"

What would happen if an asteroid hit Earth?

Let's imagine a ten-kilometre-wide dinosaur-killer asteroid* struck again...

* Image not to scale

Global damages
Following the initial impact, Earth's temperature would be raised to a level inhospitable to most life on the planet.

Crater
The resulting crater would be more than 100km (62mi) across and easily visible from space.

Ejecta
Some debris would be flung back into space, before it rained back down again over the entire Earth.

Thermal radiation
The atmospheric temperature after the impact would be more than 1,000ºC (1,800ºF), cooling again over time.

Seismic effects
Huge shock waves from the impact would trigger both earthquakes and volcanic eruptions around the world.

Energy
It would hit Earth with an energy of 100 million megatons - 2 million times more than our most powerful atomic bomb.

Air blast
An air blast would flatten anything within an area the size of North America, with hurricane-force winds extending another 1,000km (620mi).

Tsunami
If the impact were in or near an ocean, a mega-tsunami taller than our highest buildings would sweep for hundreds of kilometres.

Asteroid Impact and Deflection Mission. In October 2022, a binary asteroid (one orbiting another), 65803 Didymos (1996 GT) and its moon Didymoon, is set to pass relatively near Earth, providing an excellent opportunity to test the proposal out.

First, ESA's Asteroid Impact Mission (AIM) spacecraft will be sent to orbit the two asteroids, launching in October 2020. In late 2022, NASA's Double Asteroid Redirection Test spacecraft will arrive and slam straight into the asteroid's moon at about six kilometres (four miles) per second.

AIM will observe the resulting change in orbit of Didymoon. The change in velocity is expected to be tiny, about 0.4 millimetres (0.02 inches) per second – smaller than we would need if the asteroid was heading our way. But this will be the first time in human history that we have actually changed the orbital characteristics of a body in the Solar System. Proving it works means that we can plan for a bigger and better mission in the future.

There are other methods on the table to deflect asteroids. One is a gravity tractor, which would involve placing a spacecraft near an asteroid and using its gravitational tug to very slightly affect the orbit of the asteroid. To do this, the spacecraft would have to keep firing its engines and remain in the same position above an asteroid. Over a long period of time, perhaps several years, the orbit would change enough to have the same effect as slamming into it.

This technique may be tested out on NASA's Asteroid Redirect Mission next decade, which would see a spacecraft pick up a large boulder from an asteroid for astronauts to study at a later date. It's currently unclear if this mission will be going ahead though, as there are some calls for it to be cut.

But if Armageddon is more your thing, you might be interested in NASA's Hypervelocity Asteroid Intercept Vehicle. This mission would involve a smaller spacecraft hitting an asteroid, creating a shallow crater. A secondary spacecraft, loaded with a nuclear device, would then enter the crater and explode, dramatically altering the trajectory of the asteroid. This sort of mission would be useful if we had a short time frame to deflect an incoming asteroid, say less than five years. But at the moment, international law prevents nuclear weaponry being sent into space. That could change, though, if the very existence of Earth were at stake.

While these proposals are all well and good, it's actually quite surprising how little we know about asteroids. We've only sent a handful of spacecraft to asteroids to study them, and each can have a different composition and shape. One upcoming mission that might change all of that is NASA's OSIRIS-REx. Set to launch in September this year, the spacecraft will collect and return a sample of asteroid 101955 Bennu for study on Earth by 2023. What scientists learn from this sample could prove invaluable in understanding asteroids.

"Understanding the detailed topography, surface properties, and the Yarkovsky effect – where sunlight can push a dark object out of its predicted orbit – are crucial for understanding how to divert asteroids," Jason Dworkin, OSIRIS-REx project scientist, tells **All About Space**. "In the case of Bennu, there is a small chance of it hitting in the late 22nd century. So with the information returned by OSIRIS-REx, we will be well prepared if a diversion plan is necessary in the next century," he adds.

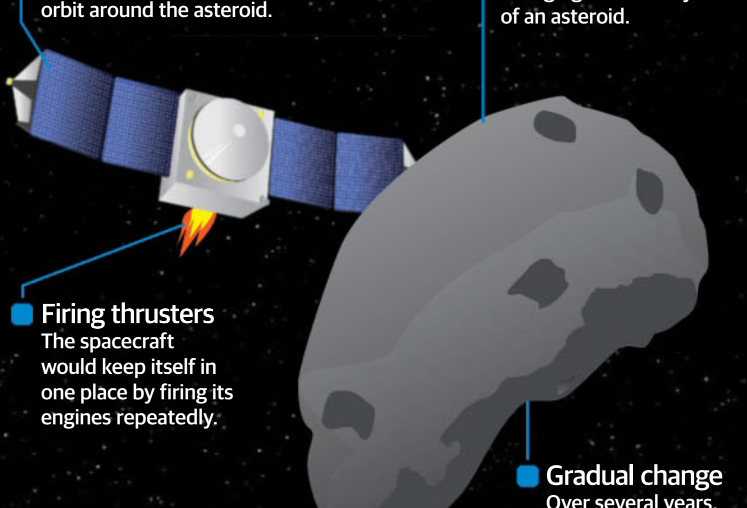
Thanks to these missions and others, we are making relatively good progress in our efforts to track and stop asteroids. But it could be argued that we are not nearly doing enough. An asteroid impact is one of

> "OSIRIS-REx will collect and return a sample of asteroid 101955 Bennu for study on Earth by 2023"

Asteroid protection plans

Some of the proposals that could save life on Earth from extinction

Gravity tractor



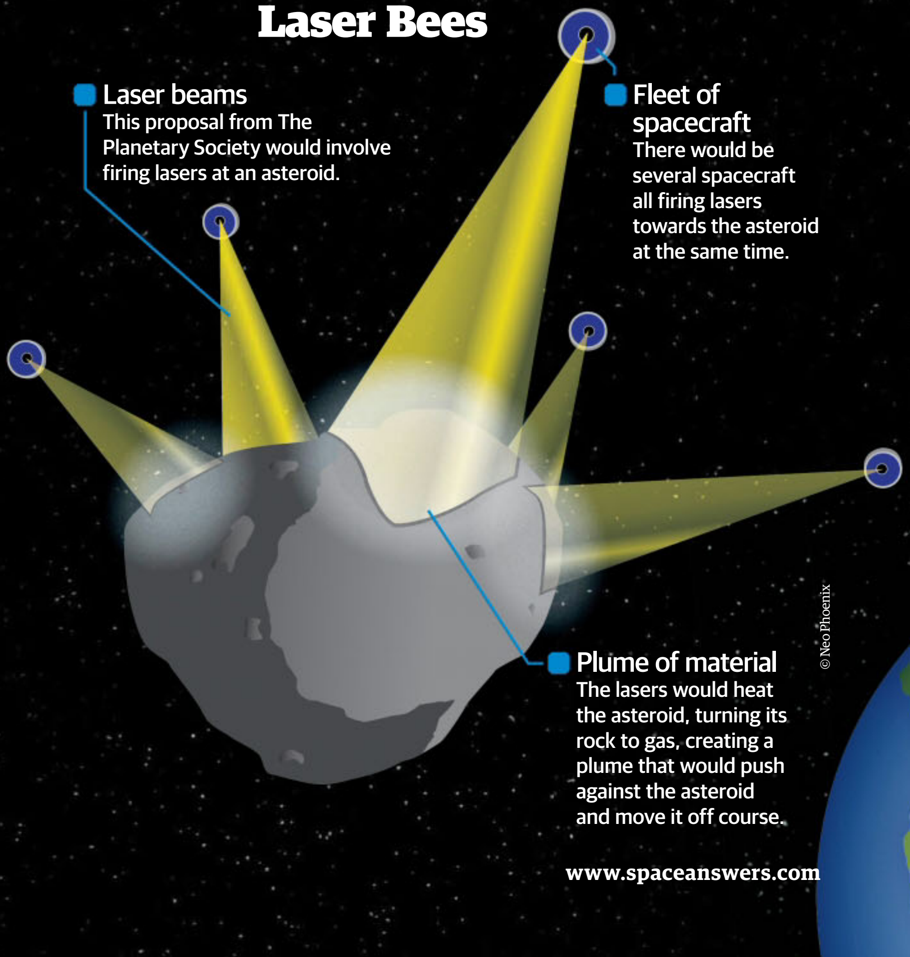
Spacecraft in orbit
This change in velocity would be achieved by having a spacecraft in orbit around the asteroid.

Changing velocity
A gravity tractor would work by slowly changing the velocity of an asteroid.

Firing thrusters
The spacecraft would keep itself in one place by firing its engines repeatedly.

Gradual change
Over several years, the gravitational tug of the spacecraft would change the speed – and trajectory – of the asteroid.

Laser Bees



Laser beams
This proposal from The Planetary Society would involve firing lasers at an asteroid.

Fleet of spacecraft
There would be several spacecraft all firing lasers towards the asteroid at the same time.

Plume of material
The lasers would heat the asteroid, turning its rock to gas, creating a plume that would push against the asteroid and move it off course.

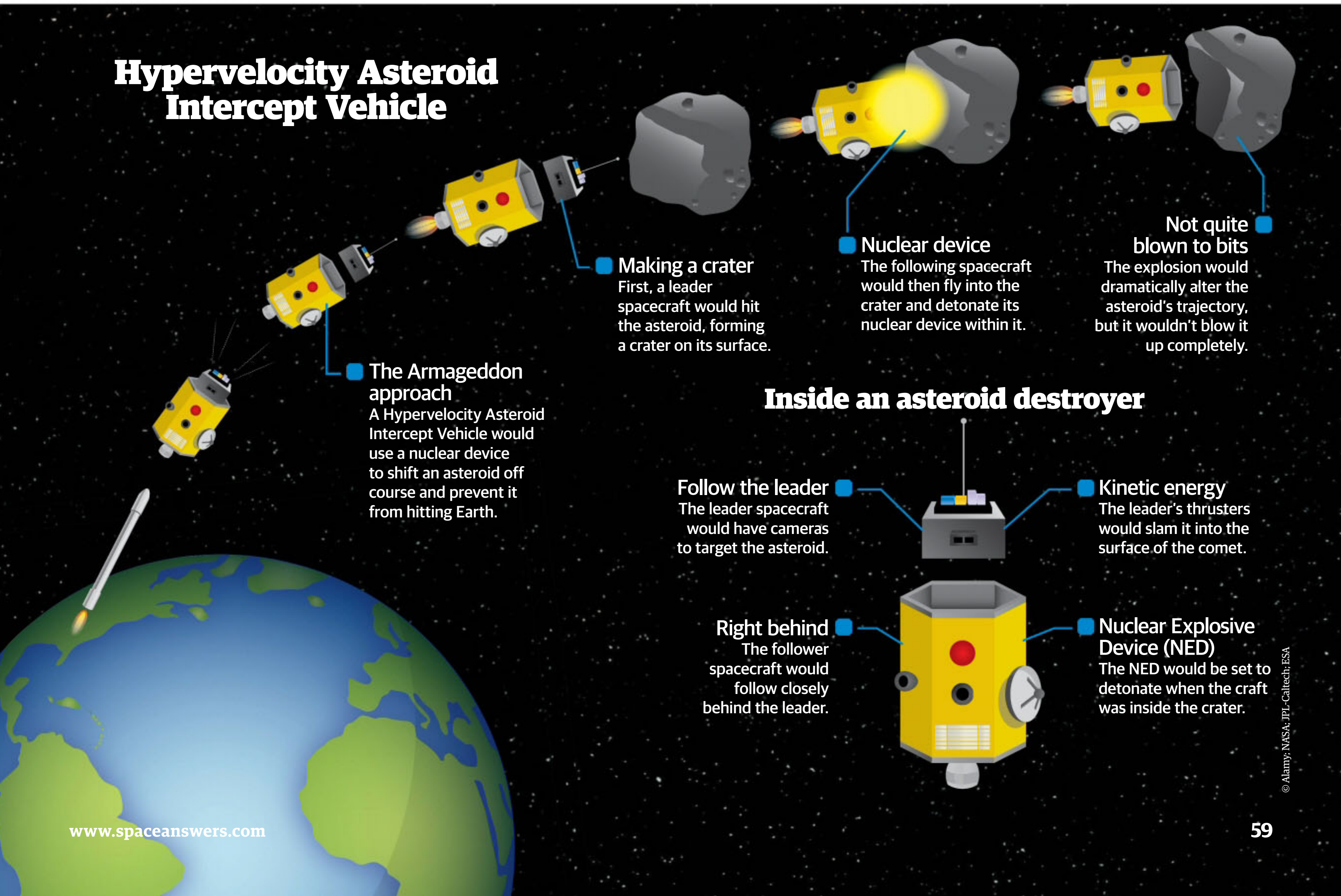
© Neo Phoenix

the few apocalyptic events that we can actually stop, so many argue that we should be doing as much as possible to make sure such an event never happens. In an ideal world, we'd already have a deflection system ready and waiting when needed, with a fleet of space-based telescopes tracking every single sizeable asteroid in our vicinity. But currently we don't. "The dinosaurs didn't have a space programme, and look what it did to them," says Richters. "We have a space programme, so why don't we solve this and figure it out?"

Asteroid Day itself, only two years old, has bigger and grander plans. Richter and his team have put forward a proposal to the United Nations for it to become an internationally recognised annual event, similar to how Earth Day highlights the issue of climate change ever year. If no objections are raised, the proposal could be approved as early as September this year. And keeping people informed through efforts like this will be key. It's not easy for governments or scientific bodies to raise the issue of asteroid impacts without being sniggered at. But the prospects of an impact are very real, and very deadly.

Missions like the Asteroid Impact Mission and OSIRIS-REx are a step in the right direction, but there is more to be done. "I hope that one day we don't need an Asteroid Day any more," says Richters. Not because Earth will be gone, but rather, we'll be ready and waiting for anything the cosmos sends our way.

NASA's troubled Asteroid Redirect Mission would send astronauts to visit an asteroid



Hypervelocity Asteroid Intercept Vehicle

The Armageddon approach
A Hypervelocity Asteroid Intercept Vehicle would use a nuclear device to shift an asteroid off course and prevent it from hitting Earth.

Making a crater
First, a leader spacecraft would hit the asteroid, forming a crater on its surface.

Nuclear device
The following spacecraft would then fly into the crater and detonate its nuclear device within it.

Not quite blown to bits
The explosion would dramatically alter the asteroid's trajectory, but it wouldn't blow it up completely.

Inside an asteroid destroyer

Follow the leader
The leader spacecraft would have cameras to target the asteroid.

Kinetic energy
The leader's thrusters would slam it into the surface of the comet.

Right behind
The follower spacecraft would follow closely behind the leader.

Nuclear Explosive Device (NED)
The NED would be set to detonate when the craft was inside the crater.

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5 AMAZING FACTS ABOUT

Hot Jupiters

The first hot Jupiter was discovered around a star like our own Sun in 1995

© ESA, NASA, G. Tinetti (University College London, UK & ESA) and M. Kornmesser (ESA/Hubble)

They're unlikely to have moons

While moons are likely to exist around planets beyond our Solar System, this isn't the case for hot Jupiters. According to research, these exoplanets compete against the high gravitational attraction and tidal forces brought about by being so close to their stellar parents, which would cause a moon's orbit to become unstable - that's if these roasted worlds could hold onto a moon in the first place.

They're like Jupiter, only much hotter

Hot Jupiters are thought to be physically similar to the king of the Solar System. But as they are on an orbit that tightly hugs their parent star, their atmospheres get roasted to exceedingly high temperatures of thousands of degrees. Being so close to their star means that days are long, and tidal locking gives them extreme and exotic atmospheres.

They were among the first exoplanets to be found

One of the well-known hot Jupiters is 51 Pegasi b, since it was the first alien world to be discovered around a star like our own Sun. Uncovered in 1995 by University of Geneva astronomers Michel Mayor and Didier Queloz, 51 Pegasi b rests 50 light years away in the constellation of Pegasus.

Their atmospheres are being blown out

Every hot Jupiter in the universe is having its puffy atmosphere stripped away by its parent star. Being so close means that these exoplanets bear the brunt of intense solar winds, leading to a loss of about 100 million to 600 million kilograms (220 million to 1.3 billion pounds) of mass per second. Occasionally, a star will unleash a deadly solar flare, which skyrockets the hot Jupiter's evaporation rate.

They don't fit the model of planetary system formation

Some hot Jupiters have been found to orbit backwards, in what is known as a retrograde orbit - something that flies in the face of our standard model of planetary formation. Rather than their orbits being disturbed, astronomers think that the hot Jupiter's star may have flipped over during the earlier years of the planetary system's formation, causing a change in the exoplanet's orbital direction.

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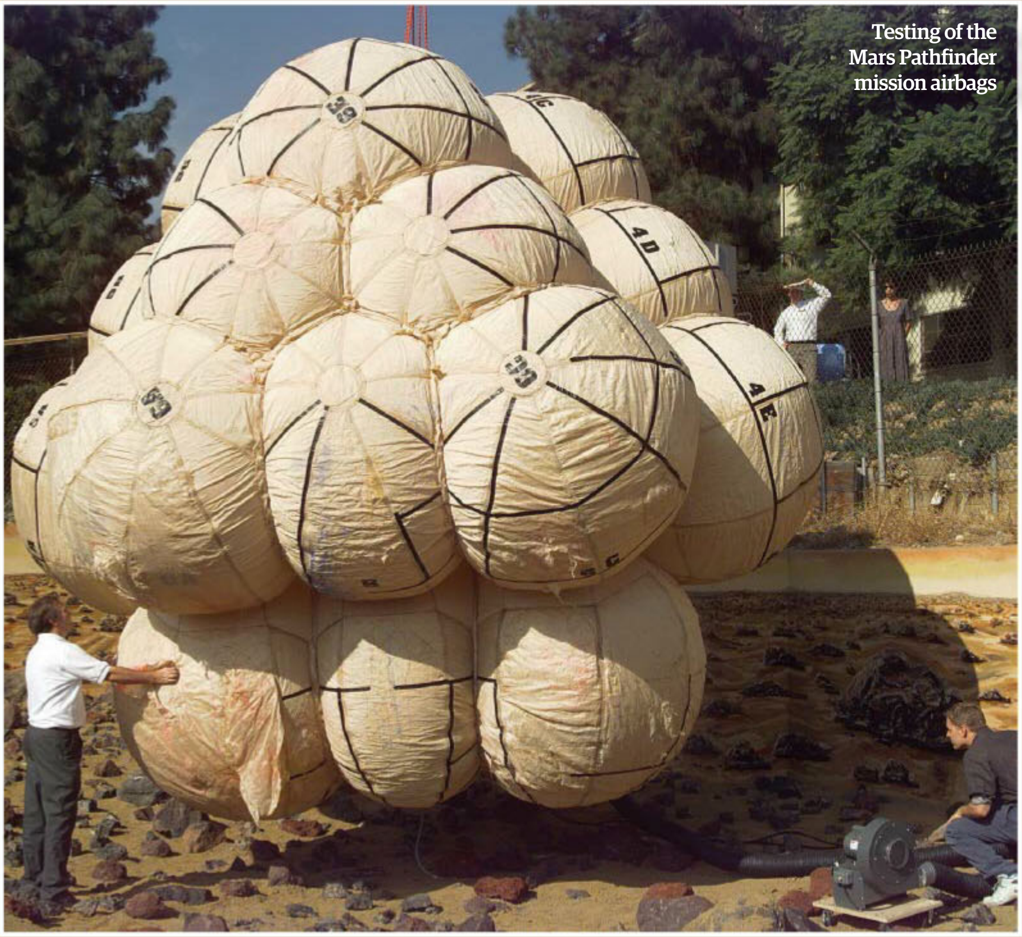
Mars Pathfinder's 'landiversary'

Nineteen years ago, the very first Mars rover touched down on the Red Planet's soil

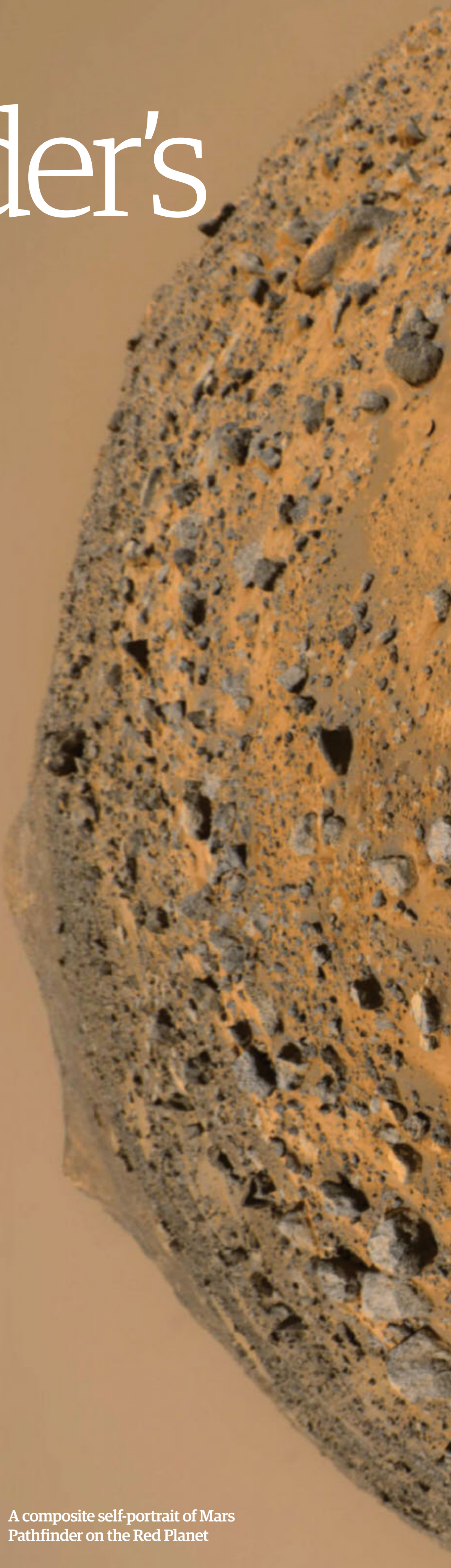
While Mars Pathfinder is no longer in operation, the mission, which consisted of a lander and a 10.6-kilogram (23.3-pound) rover named Sojourner, is recognised as the very first robot to operate outside of the Earth-Moon system, as well as the first spacecraft to explore the Red Planet in more than 20 years.

After landing safely on the surface of Mars on 4 July 1997, the first set of data was released within hours, followed by images 4.5 hours later. The Sojourner rover then began its trek of the Martian surface, returning images and other data over the course of three months. Providing a tremendous amount of new information about the Red Planet thanks to exceeding its life expectancy by almost three times over, NASA's Mars Pathfinder mission completed its final transmission on 27 September 1997. In total, it provided 2.3 billion bits of data, including more than 16,500 images from the lander and 550 from the rover, as well as chemical analysis of rocks and soil, and studies of the Red Planet's winds and weather. These findings revealed that Mars once owned a warmer, wetter surface with a thicker atmosphere in its past.

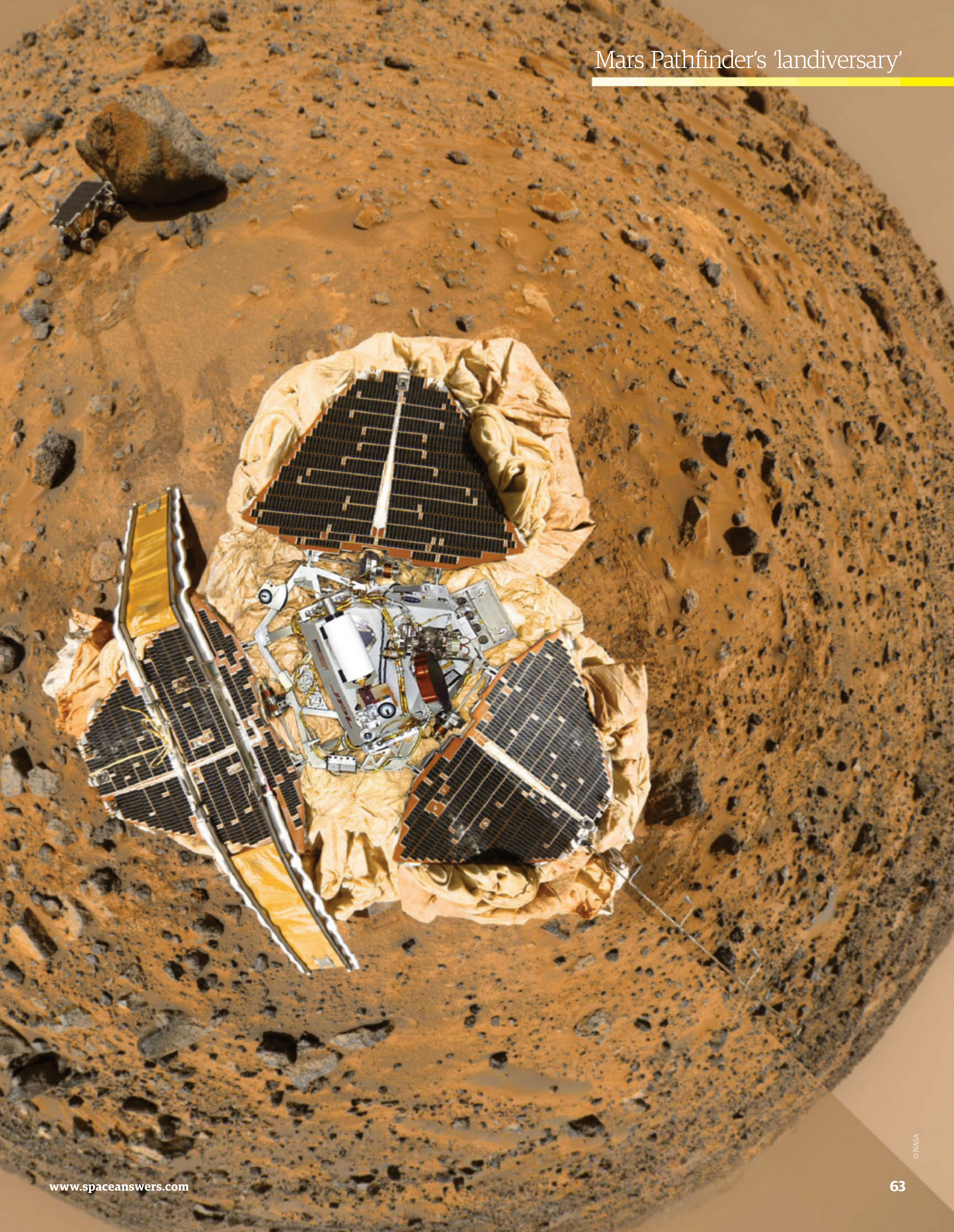
When the mission's managers failed to re-establish contact five months after its final information transmission, the lander was renamed the Sagan Memorial Station in honour of astronomer Carl Sagan. It is situated at the ancient flood plain in Mars' northern hemisphere called Ares Vallis, or the Valley of Ares, which is one of the rockiest parts of the Red Planet.



Testing of the Mars Pathfinder mission airbags



A composite self-portrait of Mars Pathfinder on the Red Planet



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INTERVIEW BIO

Robin Ince

Although comedian Robin Ince graduated from university with a degree in English and drama, he has become one of the best-known voices for science in the UK. Inspired by science populariser and astronomer Carl Sagan, Ince has been presenting the popular BBC Radio 4 show *The Infinite Monkey Cage* with physicist Brian Cox since 2009. The stand-up comedian provides a witty look at the scientific world and irreverently engages with a host of expert and celebrity guests. Ince also hosts a regular podcast called *The Cosmic Genome*.

> "Enjoy the ride. Pick up books on space exploration, quantum mechanics and artificial intelligence. Don't expect to be able to build a sentient robot by the end. Just enjoy building up these ideas"

Monkeying around with space

The *Infinite Monkey Cage*'s Robin Ince is a comedian with a mission: to prove that space can be a serious laughing matter

Interviewed by David Crookes

You graduated from university with a degree in English and drama, but what inspired your passion for science?
Well, in terms of expertise, I have no [expertise] in anything but I was always interested in science. Yet when I was about 13 or 14 years old, I got a particularly terrible exam result in physics and it really put me off the subject. It was one of those things that happened during the change between schools and I don't think our physics teacher realised we weren't all up to the same stage.

Did you find it wasn't being taught in a way that worked for you?
Teaching science, I think, can be problematic because it seems entirely separate to the world around you. There's this series of equations and ideas that sometimes are not connected to everything that you see. That's why I think the great science popularisers and communicators are those who will show you something that you have experienced and then get you to think about that moment when you're looking up at the Moon or something. It could just be about the heat of water or why you see your reflection in a pane of glass, but all of those things that make you think, "Oh, this is science; everything is science."

How did you get back into science, though?
When I was in my mid-20s, I read *The Demon-Haunted World* by Carl Sagan. Of course, when I was around ten years old I would watch *Cosmos* and I loved Carl Sagan. That was really the thing that ignited my interest in science.

Would you describe yourself as a scientist now?
No, no, no, no. If I call it a job – which may actually be an exaggeration to anyone who actually has a job they have to do – then it's to make people excited about ideas. All my shows, whether they are my stand-up shows, the shows that I make on the radio with Brian [Cox], or the documentaries I make without him, are about making people excited. But most of what I read about is science – most of my days are at some point spent trying to interrogate something in the world, whether biochemistry, epigenetics or particle physics, but I'm not in any way a scientist. I am science-interested; I'm a curious human. That is all I am.

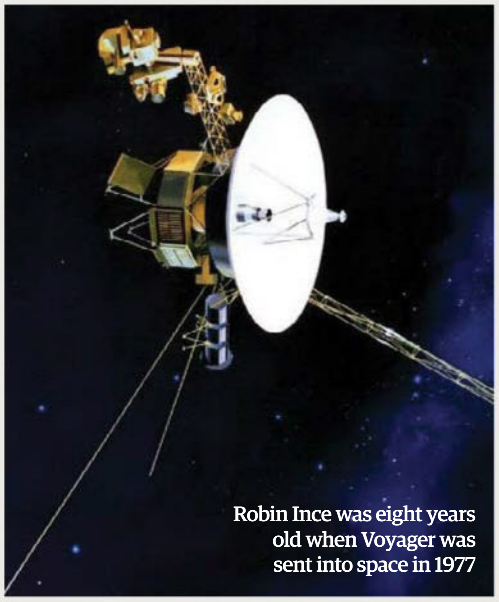
Were you proud to become an honorary doctor of science, though?
You see, that's the terrible thing. I have a couple of those things and [physicist] Richard Feynman always said that we should turn them down. But, of course, I realised Richard Feynman was always in with a chance of winning a Nobel Prize, whereas I'm not so, you know, when someone does say, "Do you want to turn up and you can put on a robe and then we'll have free very small pieces of pastry and wine?" Then I say, "Yeah, why not?"

You mention Carl Sagan a lot in your show on BBC Radio 4, *The Infinite Monkey Cage*. What was it about his programmes in the 1980s that caught your imagination?
I still think they are some of the greatest programmes in terms of dealing with a kind of understanding of why the universe appears to be as it is. The programmes start beautifully anecdotally. One I remember in particular involves the story of the Heike crab, which he uses to talk about evolution. There's this wonderful story involving a child emperor and it's melancholy and melodramatic and then it ends up with this story involving a crab, which I've since found out may be a slightly flawed story. But that doesn't matter. The story itself was a springboard into 50 minutes, which was a fantastic primer in understanding natural selection and evolution. Even when Sagan's talking about things like the Doppler effect and how he got his own understanding of the expanding universe, he starts off with ten minutes of delightful story. And that's where a lot of teachers have a problem.

In what sense?
They are up against the wire to make sure they have taught all the things they are supposed to. They don't have the time to say, "You know what, today's lesson is just going to be a story and then this story is going to be your doorway into understanding this particular idea" – or at least be willing to go on a journey to understand it. I was at [physicist] Fay Dowker's first lecture on general relativity with a set of third year university students. It was the first time they had touched on general relativity and it was fascinating to see these people, who have spent ten or 15 years since their first science assignment, finally being primed enough in the language of physics to be able to approach this fantastic and beautiful

Robin Ince and Brian Cox co-present BBC Radio 4's *The Infinite Monkey Cage*

Ince identifies the images sent back by the Curiosity rover as one of the biggest scientific breakthroughs



Robin Ince was eight years old when Voyager was sent into space in 1977

idea. When you have seen the excitement in young people's eyes, it gives you the encouragement to make a show that gets people excited about ideas.

Is there a certain knack to getting the right balance in a show?

Well, you have undergraduates who are able to approach general relativity and eventually understand it with a depth that will elude me until my dying day, but we want to explain to people that you don't have to have total comprehension. With science, we're constantly dealing with the idea of understanding the least wrong version of events. That's what science is - it is constantly going, "right, here's an idea and this is definitely less wrong than the previous version." As we know, Lord Kelvin was wrong when he said, "There is nothing new to be discovered in physics now," because shortly after that there was the incredible revolution in quantum.

Can science be daunting to a lot of people?

That's the thing. It's important that people don't pick up a book on quantum mechanics, read it and, at the end think, "I don't understand it, I must be an idiot and I must never read it again." Enjoy the ride. Pick up books on space exploration, quantum mechanics and artificial intelligence. Don't expect at the end of the book or the documentary that you'll be able to build a sentient robot. Just enjoy building up these ideas. This is great. Every now and again I look out of the window and things look slightly different to me today then they did yesterday because I have learned new things about our understanding of the universe.

***The Infinite Monkey Cage* has been running since 2009. Why do you think it's been so popular**?

One of the things about radio is that you are allowed to make the thing that you want. It's basically three people - Brian [Cox], our producer Sasha [Feachem] and me, together with the other people who are involved, like the BBC's head of science, and there's a hands-off approach. We're allowed to sit down and say, "What are the six things we want to do in the next series?" And we choose the guests ourselves. It's something we feel we own; it's our show and we're not just coming in as presenters.

Every show that we make is a show that we really want to make and I think, perhaps, its success is that it has allowed us to just be the people that we are. Brian is a fantastic communicator of scientific ideas and I'm reasonably good at being facetious towards him when he's gone too far and I realise the audience are being lost. But underneath it all, we have a lot of similarities. We are friends and we just really, really love it and I hope it comes across. There's that lovely quote from Carl Sagan when someone said, "Why do you want to communicate these ideas?" And he said, "When you're in love you want to tell the whole world." And that's a beautiful way of putting it.

Do you get a lot of feedback from listeners?

With every show the excitement when you get emails and letters from ten-year-olds and 89-year-olds with their own ideas and questions, confusions or illuminations from what they've heard, it means you think this is part of the conversation. Also, we are not trying to say, "Here is a half-hour module on this subject." We write three sets of questions the afternoon before the show and talk about the ideas and we never really get past the first set of questions.

Do you run into complaints about the show? Are there any accusations that it's too scientific?

There is always going to be a battle when you popularise scientific ideas. You have some scientists who see it as frivolous and pointless and they ask, "Why are you being so silly with this?" Our general relativity shows went out in a different time slot and were in a slightly different format. I thought it was worrying in some ways because people have got used to what we're like at 4.30pm but for people who normally tune in to Radio 4 at 9am, well, they may think, "Who are these idiots?" But we received some of the most positive stuff we've ever had. There were just two who said we had done it entirely wrong, and what they meant was that, with science programmes, you should deal with them in a way that has a tremendous amount of gravitas. It's serious minded, do not be playful. But nearly all of the scientists that I know and interview are tremendously playful people.

The greatest scientists we know from history - Einstein or Feynman, or many Nobel Prize winners like Paul Nurse - are very playful people. And that's what we're trying to get across. You don't have to say, "Welcome to science. Today we are looking at general relativity. This idea..." You can mess around. Sometimes I think, "My God, we did a show about dark energy and dark matter. We should have done one or the other and seven minutes was just me messing around with Jon Culshaw." But the next 23 minutes was mostly hard science. I'm there to mess around and lure people into a false sense of security.

Of all the scientists you've met, who has been the most inspirational and fun do you think?

One of Robin Ince's most inspiring locations is Jodrell Bank Observatory in Cheshire

Comedian Ben Miller (left), Professor Brian Cox (middle) and comedian Robin Ince (right) use their talents to make space exciting, fun and engaging for all

"With science, we're trying to understand the least wrong version of events"

When I go to Jodrell Bank [Observatory], it's great to sit down with someone like Tim O'Brien as he explains how the Lovell Telescope works and to get a chance to stand in the dish. All of the radio waves that are being fed in via this dish help us to understand about pulsars and quasars.

In terms of communicating ideas of space, I'd say Chris Hadfield – I know he's an astronaut rather than a scientist but it's the way he frames his experiences of being on the International Space Station [ISS] and looking back down on Earth and how that changes him as a human. I think he's fantastic at communicating and has done an enormous amount to excite people about human space exploration, plus it's hard not to be excited meeting an astronaut.

I remember that moment the day Neil Armstrong died, I walked down the South Bank [in London] and looked up at the Moon, which looked particularly vibrant because it was a harvest moon, thinking, "Oh my God, at some point on this planet we may well return to a time when there is not a living human being who has stood on the Moon." But, of course, we see so much excitement in terms of journeying to Mars, who knows what will come from that?

I've read that Brian Cox wouldn't want to go into space. Is that true of yourself?

It's certainly true of me. I don't have the temperament to go into space. When you meet astronauts, they have this incredible control and it's remarkable. If I can't get the lid off a jam jar, I'd be looking at throwing it at the cupboard and there'd be jam everywhere. I'm not the sort of person to have on the ISS. But I think Brian would like to pop up on the Virgin [Galactic] thing – the idea of bouncing to the outer atmosphere and back again. I think he's definitely keen to do that. But I would imagine he's got to an age now. I know he looks young but it would be tremendous jeopardy putting someone of Brian's age up there. Gravity would mean that a lot of the glue that keeps his skin and hair in place to make him appear so young would come loose, and people would see the hideous reality of his ravished visage.

What is the biggest scientific space breakthrough?

When we see something like Curiosity on Mars, the idea that we have incredibly clear images of the surface of Mars is amazing, even though it's very parochial in terms of the size of our galaxy. I think there are also remarkable things when you look at the longevity of space exploration. Voyager was the fastest human-made object to go into space and the fact that I was eight when it launched and over 40 when it reached the 'edge' of our Solar System is incredible. The signals and images that have been gathered over those decades allow us to become familiar with the surroundings of our Solar System.

What space advances are of interest to you?

One thing that intrigues me is the way that we are developing machines that can interrogate various territories. We're looking to create objects that have a level of thought to them, and that is of tremendous importance. We'll question whether we should send humans into space: will that be an advantage or should we create machines with a level of thought to ask the right questions? What are the right things to send towards a planet, and what will have the ability to have some form of 'judgement'? I also think, in terms of the speed that we can send things into the universe, that we are waiting for an enormous breakthrough but it would mean we can really begin to get further out of our own Solar System.

If you could travel back in time and interview any astronomer from the past, who would you choose?

From a tittle-tattle point of view, I want to find out how much Galileo deserved what he got from the Pope for being facetious. I'd also be tempted to go much further back to someone like Lucretius, to go into that point where you have texts written thousands of years ago that appear to show that we then ended up in this appalling Dark Age; a period of time when we didn't seem to make the same radical progress. When you look at what Lucretius was saying about ideas of what it means to be human in the universe and his judgement on the stars, you think of all that knowledge that was lost. And of written record. Also, I would love to see Tycho Brahe's nose up close because there are so many legends that it was merely brass and not gold. So I would go back to somewhere between Lucretius, for his level of understanding without necessarily having any of the tools like telescopes, and Tycho Brahe for the tittle-tattle of his nose.

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YOUR QUESTIONS ANSWERED BY OUR EXPERTS

In proud association with the National Space Centre *www.spacecentre.co.uk*

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Education Team Presenter
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Science Writer
Robin has a degree in physics with space technology and a master's in hybrid rocket engine design. He contributes regularly to **All About Space**.

SPACE EXPLORATION

Why did the Hubble Space Telescope need to be fixed in the 1990s?

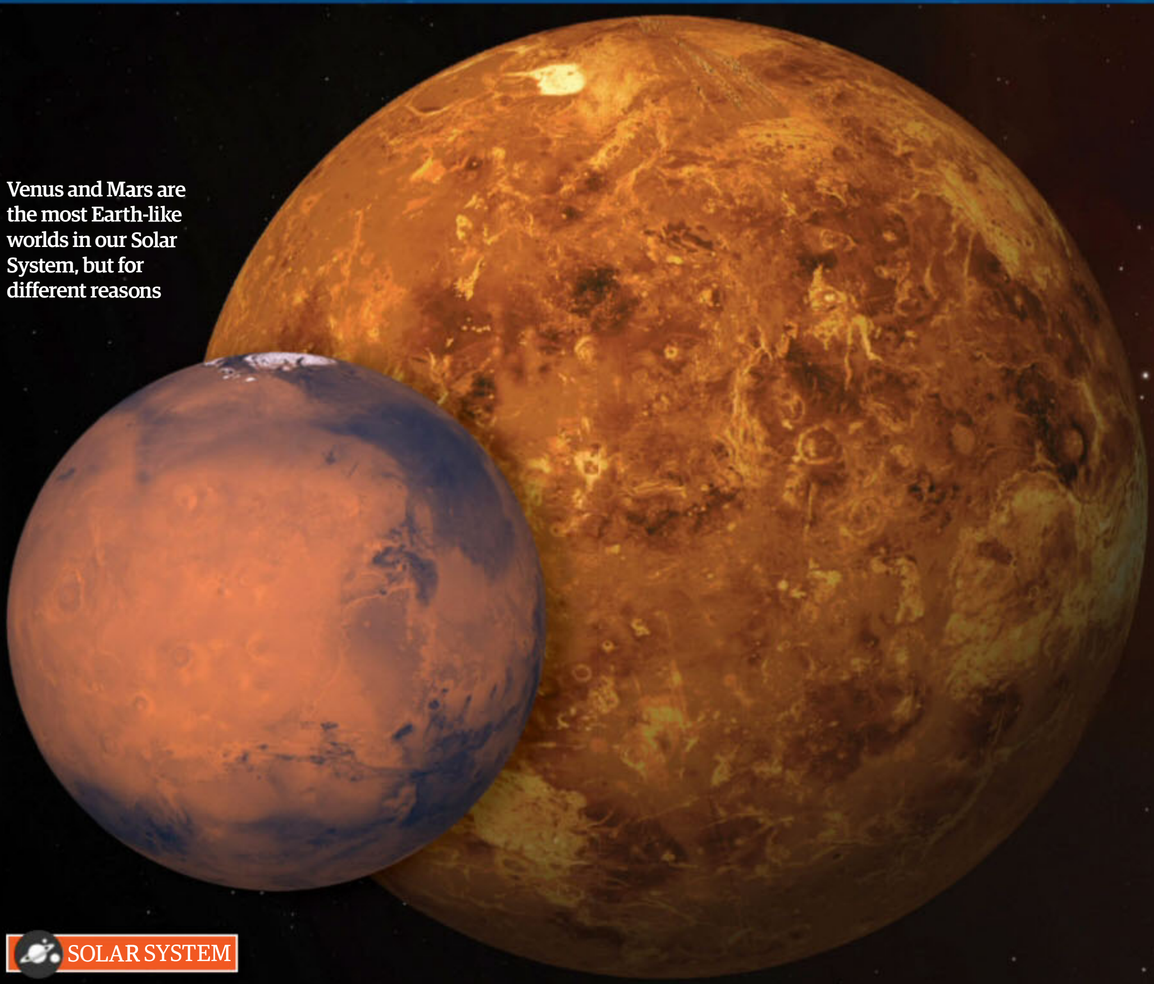
Nathan Bridge

The primary mirror had a flaw known as a spherical aberration – the edges were too flat, which meant that the light was not properly focused, causing a fuzzy halo to appear in every image. There was public outcry, and NASA came under attack for wasting money on a scientific disaster.

In 1993, NASA launched a heroic rescue mission to save the ailing space telescope. Seven crew members carried with them the Corrective Optix Space Telescope Axial Replacement (COSTAR). This specially constructed piece of equipment was made up of five pairs of mirrors that, when installed in front of the Faint Object Spectrograph, the Goddard High Resolution Spectrograph and the Faint Object Camera, would work like a pair of glasses to bend the light, bringing it into focus.

They also took the car-sized Wide Field Planetary Camera 2, which included its own corrective optics, and boosted Hubble's ultraviolet vision. **JB**

COSTAR effectively works as a pair of glasses for the Hubble Space Telescope



Venus and Mars are the most Earth-like worlds in our Solar System, but for different reasons

SOLAR SYSTEM

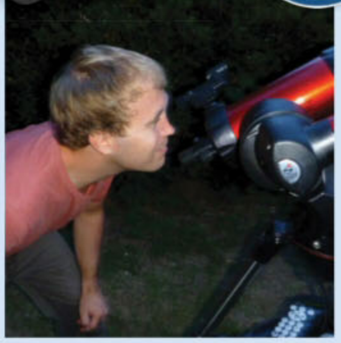
Are any of the planets in our Solar System regarded as Earth-like?

Lauren Williams

It's said that two planets in our Solar System, our neighbouring worlds Venus and Mars, are the most Earth-like. On the one hand, despite its toxic atmosphere, Venus is the most similar planet to Earth in terms of size, mass, average density and surface gravity.

On the other hand, Mars is most like our home planet in other ways - one Martian day is just over 24 hours and the Red Planet's rotational axis is tilted at around the same angle as the Earth's. Perhaps a much more interesting past characteristic of Mars, however, is that it could once have hosted liquid water on its surface - just like Earth does now. **SA**

ASTRONOMY



Humanity has been gazing skywards for thousands of years

Do we know who the first astronomers were?

Brian Neville

The first recorded written example of astronomy is around 3,500 years old and comes from Mesopotamia. Babylonian writings and star charts mapped out the sky and made constant reference to the names of stars, which were given to them by the Sumerians. This suggests that the Sumerians were probably observing the sky back in the early Bronze Age.

Confirmation of the earliest astronomer is tricky to find, as we believe that people have always studied the sky. Archaeologists have found solar observatories from 5000 BCE that were built in central Europe. These henges are designed to line up with the position of the Sun and sometimes the Moon at various times of the year, usually the solstices. **JB**

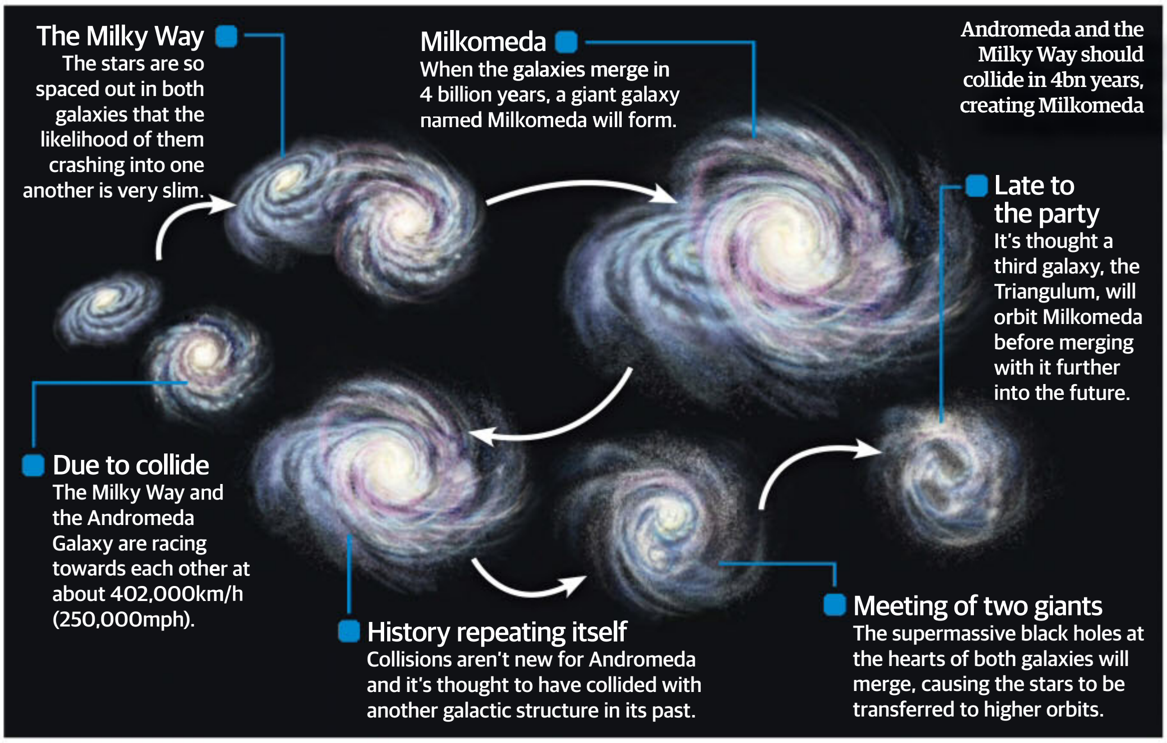
DEEP SPACE

Is Andromeda the only galaxy we're on a collision course with?

Sharon Benkhoff

As far as we know, Andromeda is the only galaxy the Milky Way will clash with. They will collide at a speed of 110 kilometres (68 miles) per second in 4 billion years. As the 1 trillion stars of the nearest galactic spiral join forces with the 300 billion stars of our galaxy, you would expect a collision of epic proportions. In some cases this is true, but in other ways it isn't.

As the stars in each galaxy are so far apart, stellar smash-ups are unlikely. But there's a 50 per cent chance our Sun could be swept out three-times further from the galaxy's centre. While it's unlikely humans will ever see this, our Solar System should remain largely unaffected. **GL**



Andromeda and the Milky Way should collide in 4bn years, creating Milkomeda

The Milky Way
The stars are so spaced out in both galaxies that the likelihood of them crashing into one another is very slim.

Milkomeda
When the galaxies merge in 4 billion years, a giant galaxy named Milkomeda will form.

Late to the party
It's thought a third galaxy, the Triangulum, will orbit Milkomeda before merging with it further into the future.

Due to collide
The Milky Way and the Andromeda Galaxy are racing towards each other at about 402,000km/h (250,000mph).

History repeating itself
Collisions aren't new for Andromeda and it's thought to have collided with another galactic structure in its past.

Meeting of two giants
The supermassive black holes at the hearts of both galaxies will merge, causing the stars to be transferred to higher orbits.

When a star dies, the planets around it often smash into each other

DEEP SPACE

How do stars smash up their planets?

Nigel Heart

Often when the star dies. For example, when a star swells into a red giant, the planets around it are smashed into each other. Comet and asteroid collisions in our Solar System have helped wipe out the dinosaurs and scar gas giant Jupiter, but that's small fry compared with what has been happening around a white dwarf called PG0843+516.

The planets that survived the death of this star formed their own demolition derby as their orbits became unstable. They crashed into one another and were pulverised until only their broken cores were left. The debris from their spectacular deaths has fallen onto the white dwarf and scientists are able to detect the chemical signature of rocky elements like iron and nickel in the dead star's atmosphere. This might be something that our Solar System has to look forward to when our Sun enters its death throes. **JB**

SOLAR SYSTEM

A nebula would appear far less impressive if we were inside it

Would we notice if the Solar System was put inside a nebula?

Shaun Luton

If we were able to walk through a nebula, we would barely notice it. Despite appearances, nebulae have a density millions of times lower than the air around us; they appear solid when we observe them from Earth because we are seeing the big picture.

As we observe these structures we are looking at objects millions of kilometres across that have a depth of a similar measurement. This results in us seeing a distinct object standing out against the featureless backdrop of space. Should we find ourselves inside one, we would appear to be surrounded by nothing apart from a brightly coloured region of space. **SA**

DEEP SPACE

How much oxygen indicates life on an alien world?

Stuart Rowe

Biological processes are thought to be a major contributing factor to the levels of atmospheric oxygen on Earth. We therefore often think of oxygen as a 'biosignature': a chemical species in the atmosphere, which is closely related to the presence of life.

Oxygen is highly reactive, so a large amount of it in an exoplanet's atmosphere suggests that there is a significant and ongoing oxygen-producing process. Although this could be attributed to alien life, there are a number of abiotic processes that could also be responsible.

As such, studying oxygen levels alone is unlikely to be enough unless combined with the study of other gases. Scientists think that finding high levels of both oxygen and another biosignature, such as methane, may be a much better indicator of life. **JB**

Finding oxygen alongside another biosignature would be a better indicator of alien life

Questions to... @spaceanswers /AllAboutSpaceMagazine questions@spaceanswers.com

ASTRONOMY

I saw a star brighten and fade quickly. What was it?

Jay Murphy

If you've ruled out a bright star disappearing behind a cloud, what you most likely saw was an Iridium flare, which are caused by the Iridium mobile phone system satellites whenever they happen to line up just right. These Iridium flares last for just a few seconds.

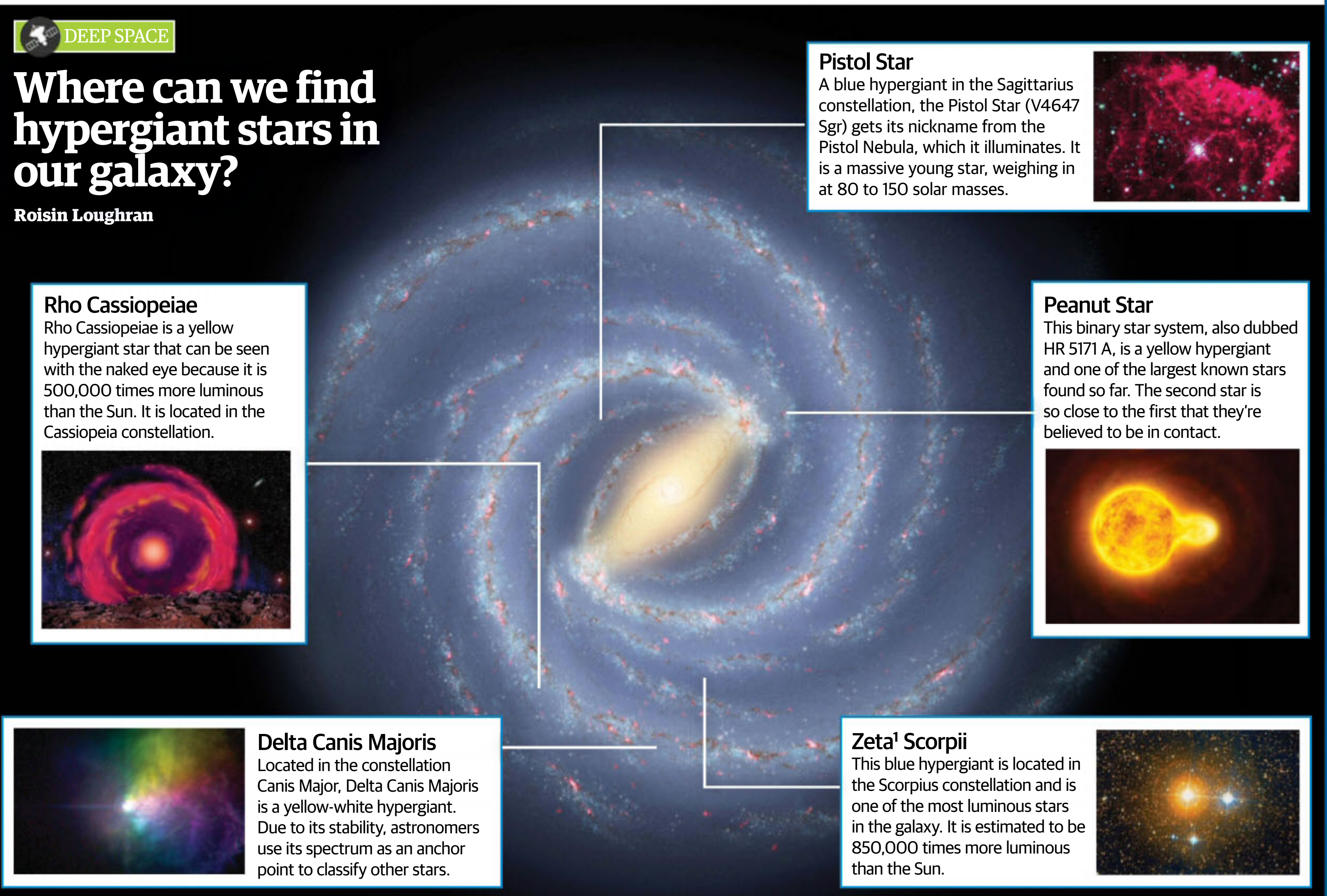
Iridium flares often look like meteors, however, if they're heading directly towards you, then they will look just like a star-like point. The same can be said for meteors if they are at just the right angle in the night sky. Given that any other astronomical event lasts longer than a few seconds, it's unlikely to be something like a supernova, which is the catastrophic explosion of a star. **GL**

Iridium flares last just a few seconds and look like meteors

DEEP SPACE

Where can we find hypergiant stars in our galaxy?

Roisin Loughran



Pistol Star
A blue hypergiant in the Sagittarius constellation, the Pistol Star (V4647 Sgr) gets its nickname from the Pistol Nebula, which it illuminates. It is a massive young star, weighing in at 80 to 150 solar masses.

Rho Cassiopeiae
Rho Cassiopeiae is a yellow hypergiant star that can be seen with the naked eye because it is 500,000 times more luminous than the Sun. It is located in the Cassiopeia constellation.

Peanut Star
This binary star system, also dubbed HR 5171 A, is a yellow hypergiant and one of the largest known stars found so far. The second star is so close to the first that they're believed to be in contact.

Delta Canis Majoris
Located in the constellation Canis Major, Delta Canis Majoris is a yellow-white hypergiant. Due to its stability, astronomers use its spectrum as an anchor point to classify other stars.

Zeta^1 Scorpii
This blue hypergiant is located in the Scorpius constellation and is one of the most luminous stars in the galaxy. It is estimated to be 850,000 times more luminous than the Sun.

SPACE EXPLORATION

What animals have been to space?

While the Russian dog Laika was famously the first animal in orbit, a surprising range of creatures have been to space

Andrew Mehigan

The world was amazed, and aghast, in 1957 when the Soviet Union launched the first animal into orbit: Laika, a stray dog from the streets of Moscow. She survived for only a few hours due to her overheating spacecraft. Laika was not the first creature in space, just the first to reach orbit. A spacecraft is in orbit when it achieves sufficient speed around the Earth that gravity is balanced by the tendency of the craft to want to fly off in a straight line. This allows the mission to stay up in space; but rockets had been flying sub-orbits, vertical flights up into space but then falling back, since 1942. The first experimental animal payload was a group of fruit flies, launched on a V2 rocket from White Sands in New Mexico in 1947.

The next animal astronaut was a rhesus monkey named Albert II who was launched in June 1949, also from White Sands. He reached 134 kilometres (83 miles) altitude, which is 34 kilometres (21 miles) further than the boundary of space, but he was lost when the parachute on his capsule failed to work. Dogs first made it to space in 1951 when the Soviet Union launched two dogs Tsygan and Dezik on an R1 rocket, a Russian development of the V2. They were the first higher organisms to be successfully recovered from space.

The US and USSR both carried out a number of animal flights during the 1950s, but it was Laika who became the first star animal cosmonaut with her orbital flight. Then, in the race to make the first human spaceflights, the newly established NASA began testing their one person Mercury capsules by flying chimpanzees, named Ham and Enos. Ham (named after the Holloman Air Force Medical Centre) made the first successful Mercury Redstone suborbital flight from Cape Canaveral in 1961, becoming America's first space celebrity in the process. Enos followed up Ham's mission later in the Mercury programme, and he preceded John Glen's first orbital Mercury Atlas mission.

Animals continued to fly to space even after humans; mice, frogs, rats, cats, newts, fish, insects, and appropriately, guinea pigs, have all been into space. However, the animal distance record belongs to some mealworms, wine flies, and a tortoise; launched in September 1968 on the Soviet Zond 5 (a stripped down Soyuz capsule). This mission circumnavigated the Moon three months before Apollo 8, making these creatures the first Earth life forms to circle the Moon. They were successfully recovered from the Indian Ocean a week later - if humans had piloted Zond 5, the USSR would have beaten the US and been the first nation to travel around the Moon. Animal research continues to be a part of the space station's programme, as a group of gene research mice flew there on the SpaceX CRS6 launch in April 2015. **RH**

Animal Launch vehicle *Location*

🔴 Survived ⚫ Did not survive

🔴 **Fruit fly** V2 *White Sands, US*

⚫ **Rhesus monkey** V2 *White Sands, US*

⚫ **Mouse** V2 *White Sands, US*

1950

🔴 **Dogs** R1 *Kapustin Yar, USSR*

⚫ **Dog** R7 *Baikonur, USSR*

🔴 **Monkeys** Jupiter *Cape Canaveral, US*

🔴 **Rabbit** R2 *Baikonur, USSR*

🔴 **Rat** Veronique *Hammaguir, Algeria*

1960

🔴 **Guinea pigs** R7 *Baikonur, USSR*

🔴 **Frogs** R7 *Baikonur, USSR*

🔴 **Cat** Veronique *Hammaguir, Algeria*

🔴 **Chimpanzee** Mercury Redstone 2 *Cape Canaveral, US*

🔴 **Tortoises** Proton *Baikonur, USSR*

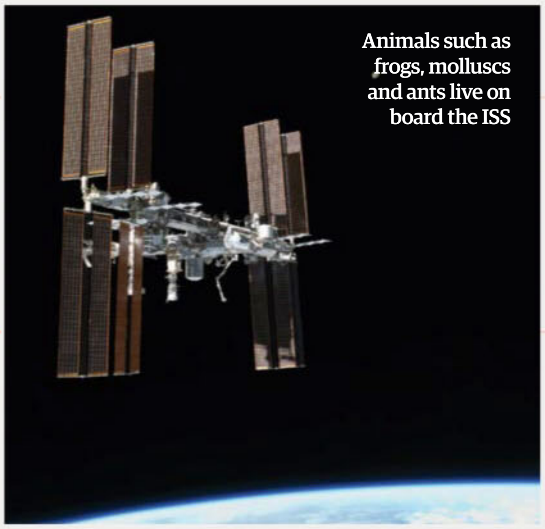
🔴 **Mealworms** Proton *Baikonur, USSR*

1970

🔴 **Fish** Saturn 1b *Cape Canaveral, US*

🔴 **Spiders** Saturn 1b *Cape Canaveral, US*

1980



Animals such as frogs, molluscs and ants live on board the ISS

🔴 **Newts** Soyuz *Baikonur, USSR*

1990

🔴 **Jellyfish** Space Shuttle *Cape Canaveral, US*

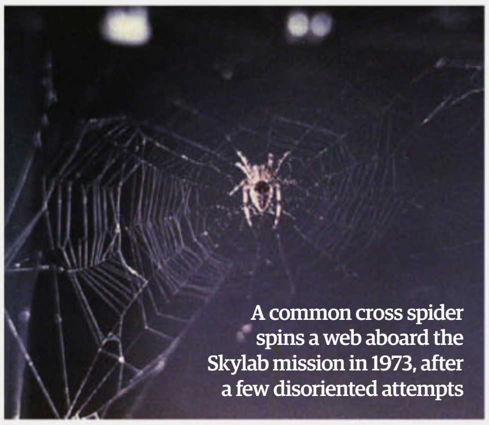
2000

⚫ **Carpenter bees** Space Shuttle *Cape Canaveral, US*

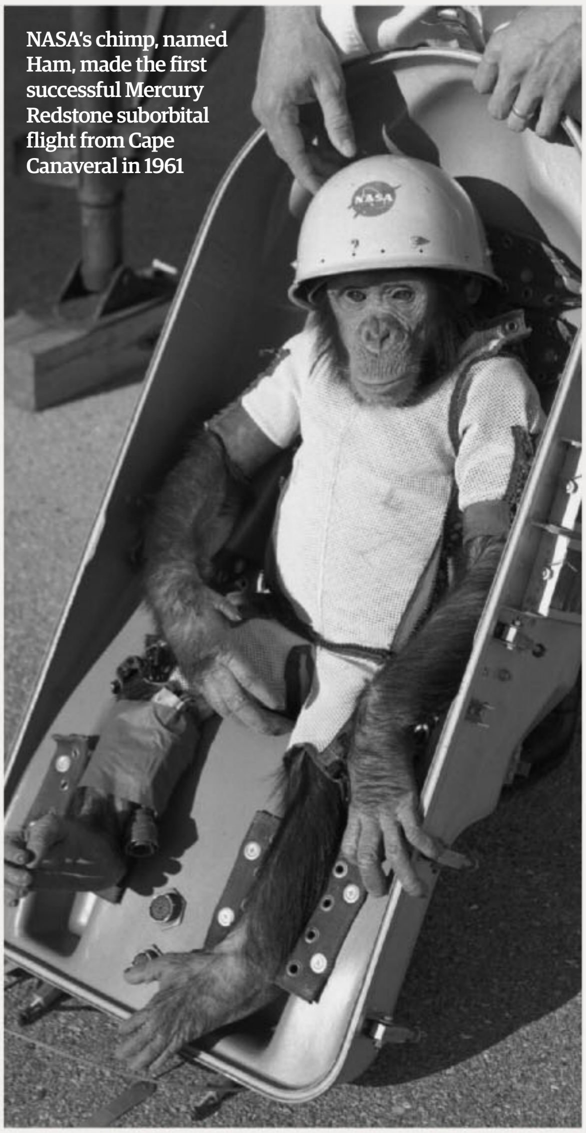
🔴 **Nematodes** Space Shuttle *Cape Canaveral, US*

🔴 **Tardigrade** Soyuz *Baikonur, Kazakhstan*

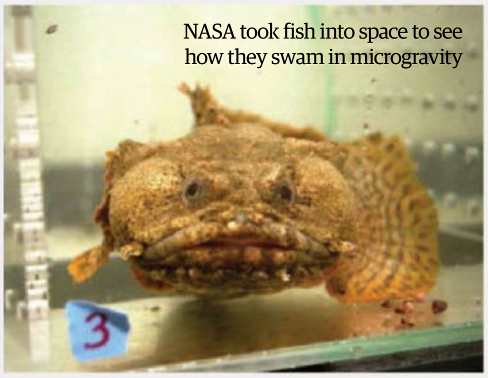
2010



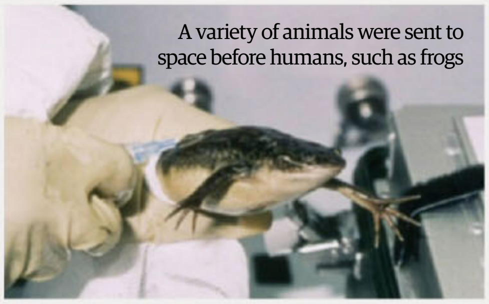
A common cross spider spins a web aboard the Skylab mission in 1973, after a few disoriented attempts



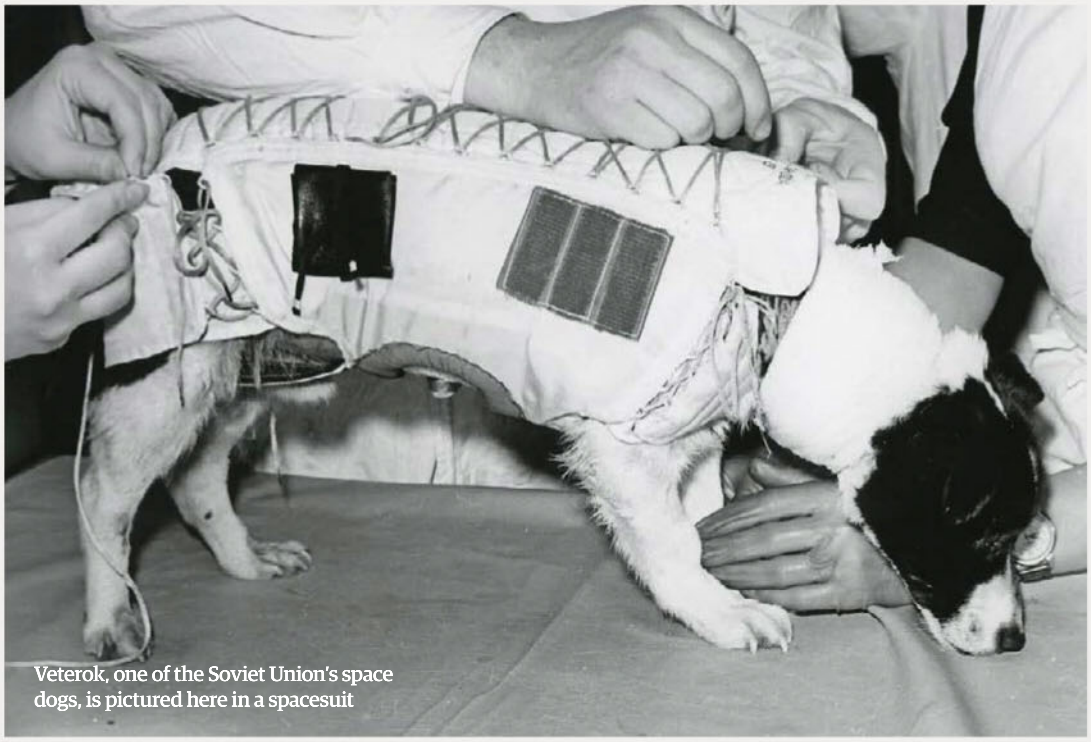
NASA's chimp, named Ham, made the first successful Mercury Redstone suborbital flight from Cape Canaveral in 1961



NASA took fish into space to see how they swam in microgravity



A variety of animals were sent to space before humans, such as frogs



Veterok, one of the Soviet Union's space dogs, is pictured here in a spacesuit

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STARGAZER

GUIDES AND ADVICE TO GET STARTED IN AMATEUR ASTRONOMY

What's in the sky?

Red light friendly

In order to preserve your night vision, you should read our observing guide under red light

29 JUN	Conjunction between the Moon and Uranus in Pisces
04 JUL	Earth reaches its furthest point from the Sun
09 JUL	Conjunction between the Moon and Jupiter in Leo
10 JUL	Comet 9P/Tempel reaches its brightest in Virgo at magnitude +12.5
16 JUL	Conjunction between the Moon and Saturn in Ophiuchus
20 JUL	Comet 81P/Wild makes its closest approach to the Sun in Leo

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Mars and Saturn are readily observable in the summer

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The summer skies are bursting with targets for the unaided eye

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Warmer nights offer delightful views of the nebulae and clusters of the summer

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A summer selection of nebulae are now readily observable

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We showcase your astroimages this month

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The Omegon MightyMak 90 is put to the test this issue

07 JUL
Pluto reaches opposition in Sagittarius with a magnitude of +14.3

08 JUL
The Capricornid meteor shower reaches its peak of five meteors per hour

10 JUL
Comet 81P/Wild reaches its brightest in Leo at magnitude +10.3

15 JUL
The Capricornid meteor shower reaches its peak of five meteors per hour

21 JUL
The α-Cygnid meteor shower reaches its peak of five meteors per hour

- Naked eye
- Binoculars
- Small telescope
- Medium telescope
- Large telescope

Jargon buster

Conjunction

A conjunction is an alignment of objects at the same celestial longitude. The conjunction of the Moon and the planets is determined with reference to the Sun. A planet is in conjunction with the Sun when it and Earth are aligned on opposite sides of the Sun.

Declination (Dec)

This tells you how high an object will rise in the sky. Like Earth's latitude, Dec measures north and south. It's measured in degrees, arcminutes and arcseconds. There are 60 arcseconds in an arcminute and there are 60 arcminutes in a degree.

Right Ascension (RA)

Right Ascension is to the sky what longitude is to the surface of the Earth, corresponding to east and west directions. It is measured in hours, minutes and seconds since, as the Earth rotates on its axis, we are able to see different parts of the sky throughout the night.

Magnitude

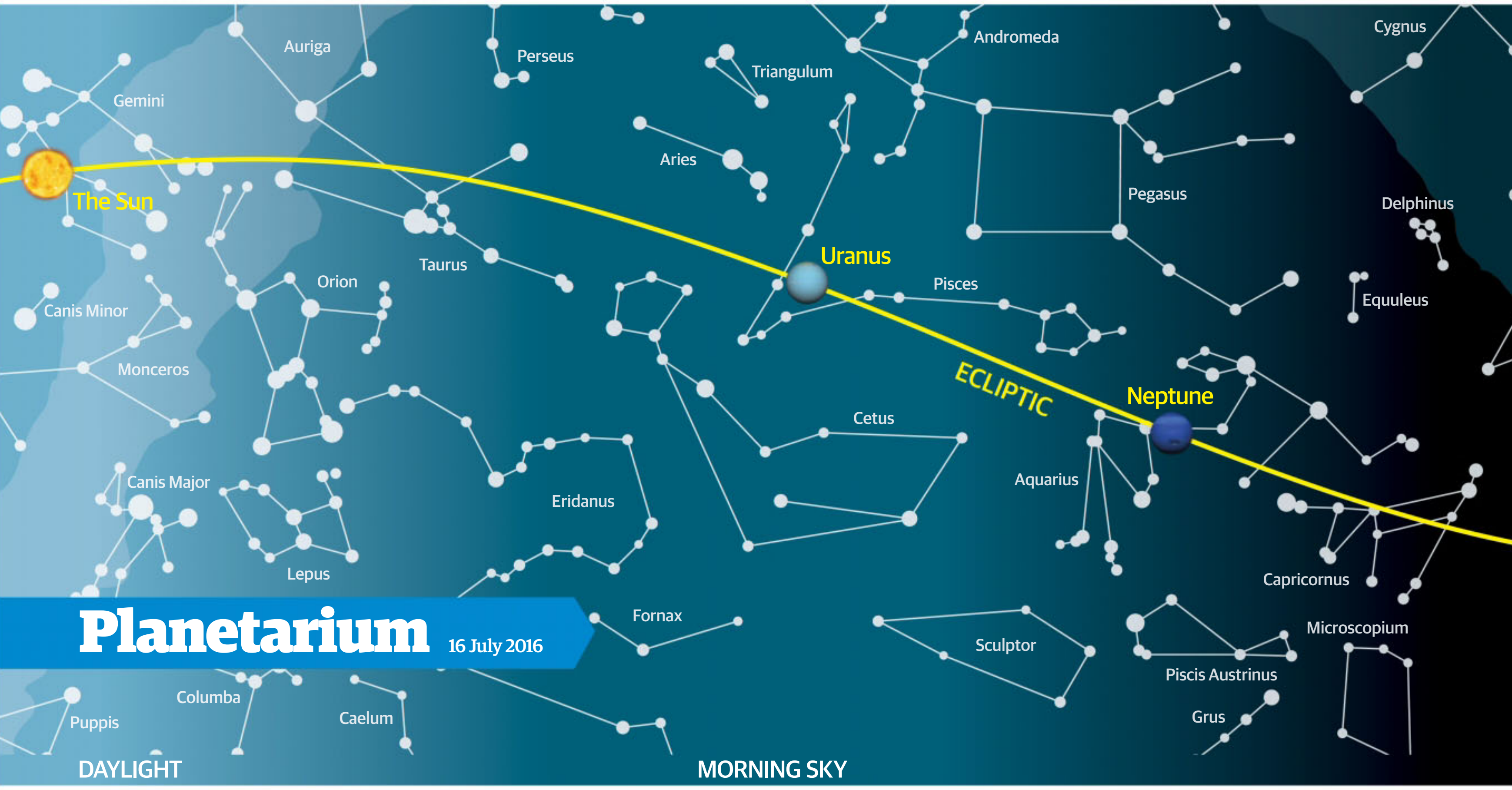
An object's magnitude tells you how bright it appears from Earth. In astronomy, magnitudes are represented on a numbered scale. The lower the number, the brighter the object will be. So, a magnitude of -1 is brighter than an object with a magnitude of +2.

Opposition

When a celestial body is in line with the Earth and Sun. During opposition, an object is visible for the whole night, rising at sunset and setting at sunrise. At this point in its orbit, the celestial object is closest to Earth, making it appear bigger and brighter.

Greatest elongation

When the inner planets, Mercury and Venus, are at their maximum distance from the Sun. During greatest elongation, the inner planets can be observed as evening stars at greatest eastern elongations and as morning stars during western elongations.



Planetarium

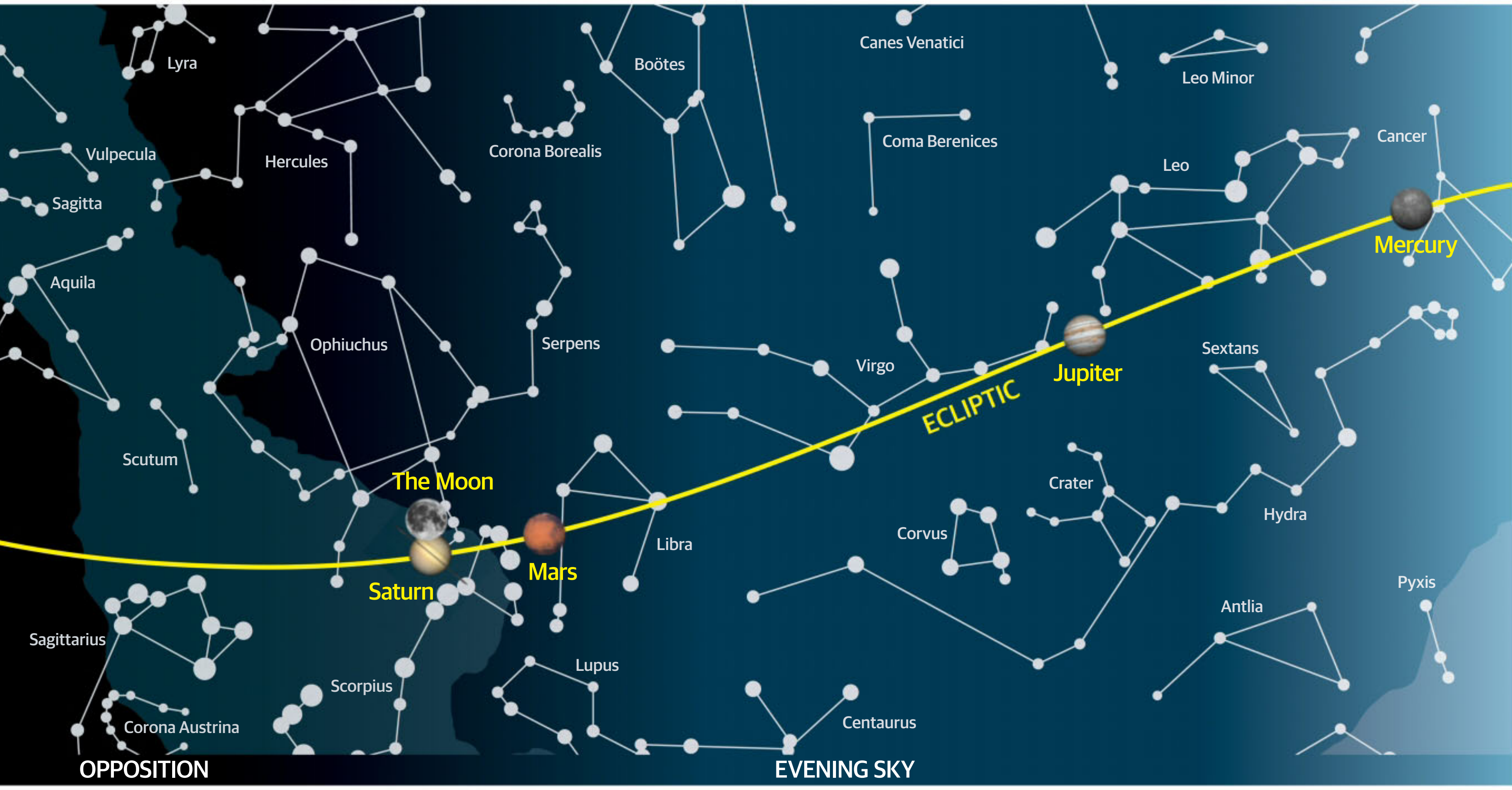
16 July 2016

Moon phases

23	JUN		92.7%	◒07:59 ◓23:08
24	JUN		86.1%	◒09:07 ◓23:41
25	JUN		77.5%	◒10:18 ◓--:--
26	JUN		67.4%	◓00:10 ◒11:32
27	JUN	LQ	56.1%	◓00:38 ◒12:46
28	JUN		44.4%	◓01:05 ◒14:02
29	JUN		32.7%	◓01:34 ◒15:19
30	JUN		21.9%	◓02:05 ◒16:36
1	JUL		12.8%	◓02:40 ◒17:51
2	JUL		5.8%	◓03:22 ◒19:02
3	JUL		1.5%	◓04:11 ◒20:05
4	JUL	NM	0.2%	◓05:09 ◒20:59
5	JUL		1.6%	◓06:12 ◒21:44
6	JUL		5.6%	◒07:20 ◓22:22
7	JUL		11.7%	◓08:28 ◒22:53
8	JUL		19.3%	◓09:36 ◒23:20
9	JUL		28.1%	◓10:43 ◒23:44
10	JUL		37.5%	◓11:48 ◒--:--
11	JUL		47.3%	◒00:07 ◓12:52
12	JUL	FQ	57.1%	◒00:30 ◓13:54
13	JUL		66.5%	◒00:54 ◓14:56
14	JUL		75.4%	◒01:20 ◓15:58
15	JUL		83.4%	◒01:49 ◓16:59
16	JUL		90.2%	◒02:23 ◓17:58
17	JUL		95.4%	◒03:03 ◓18:53
18	JUL		98.5%	◒03:51 ◓19:44
19	JUL	FM	99.9%	◒04:45 ◓20:29
20	JUL		98.8%	◒05:47 ◓21:09
21	JUL		98.6%	◒06:55 ◓21:44

%	Illumination
◓	Moonrise time
◒	Moonset time
FM	Full Moon
NM	New Moon
FQ	First quarter
LQ	Last quarter

All figures are given for 00h at midnight (local times for London, UK)



Illumination percentage

	30 JUN	7 JUL	14 JUL	21 JUL
MERCURY	90%	100%	100%	90%
VENUS	100%	100%	100%	100%
MARS	90%	90%	90%	90%
JUPITER	100%	100%	100%	100%
SATURN	100%	100%	100%	100%

Planet positions

All rise and set times are given in BST

	Date	RA	Dec	Constellation	Mag	Rise	Set
MERCURY	23 Jun	04h 59m 14s	+21° 43' 55"	Taurus	-0.9	03:46	19:56
	30 Jun	05h 59m 17s	+23° 47' 55"	Taurus	-1.5	04:04	20:43
	07 Jul	07h 05m 28s	+23° 57' 50"	Gemini	-2.0	04:41	21:23
	14 Jul	08h 09m 11s	+21° 58' 36"	Cancer	-1.5	05:31	21:45
	21 Jul	09h 04m 59s	+18° 26' 11"	Cancer	-0.7	06:23	21:49
VENUS	23 Jun	06h 26m 54s	+23° 54' 32"	Gemini	-3.9	04:58	21:39
	30 Jun	07h 04m 26s	+23° 28' 22"	Gemini	-3.9	05:11	21:46
	07 Jul	07h 41m 34s	+22° 28' 16"	Gemini	-3.9	05:28	21:48
	14 Jul	08h 18m 01s	+20° 56' 07"	Cancer	-3.9	05:47	21:46
	21 Jul	08h 53m 36s	+18° 54' 46"	Cancer	-3.9	06:08	21:41
MARS	23 Jun	15h 20m 27s	-20° 55' 43"	Libra	-1.9	18:01	02:24
	30 Jun	15h 18m 53s	-20° 59' 39"	Libra	-1.8	17:32	01:54
	07 Jul	15h 20m 09s	-21° 11' 23"	Libra	-1.7	17:07	01:27
	14 Jul	15h 24m 50s	-21° 30' 38"	Libra	-1.5	16:46	01:01
	21 Jul	15h 20m 27s	-21° 56' 17"	Libra	-1.4	16:28	00:37
JUPITER	23 Jun	11h 09m 44s	+06° 42' 44"	Leo	-1.9	11:23	00:42
	30 Jun	11h 12m 59s	+06° 21' 04"	Leo	-1.9	11:00	00:16
	07 Jul	11h 16m 35s	+05° 57' 09"	Leo	-1.9	10:38	23:46
	14 Jul	11h 20m 30s	+05° 31' 11"	Leo	-1.8	10:17	23:20
	21 Jul	11h 24m 43s	+05° 03' 24"	Leo	-1.8	09:56	22:55
SATURN	23 Jun	16h 40m 45s	-20° 24' 06"	Ophiuchus	+0.8	19:18	03:47
	30 Jun	16h 38m 51s	-20° 21' 25"	Ophiuchus	+0.9	18:48	03:18
	07 Jul	16h 37m 07s	-20° 19' 10"	Ophiuchus	+0.9	18:19	02:49
	14 Jul	16h 35m 38s	-20° 17' 26"	Ophiuchus	+0.9	17:49	02:21
	21 Jul	16h 34m 25s	-20° 16' 18"	Ophiuchus	+0.9	17:21	01:52

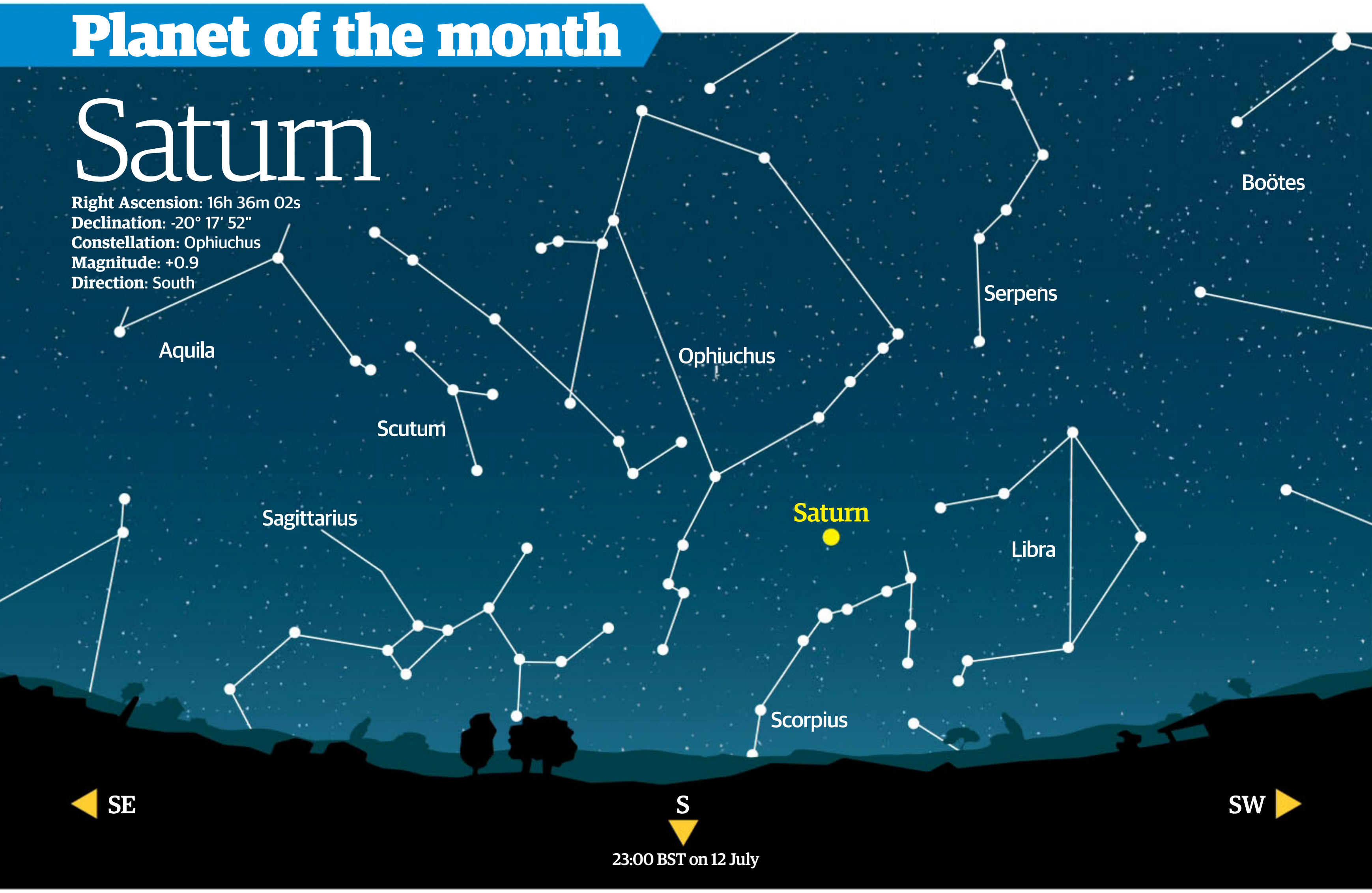
This month's planets

Of the Solar System's five bright planets, Mars and Saturn are readily observable in the summer

Planet of the month

Saturn

Right Ascension: 16h 36m 02s
Declination: -20° 17' 52"
Constellation: Ophiuchus
Magnitude: +0.9
Direction: South



23:00 BST on 12 July

Following its opposition on 3 June, Saturn's observational circumstances in this period still render it the UK-based astronomer's best opportunity to view the ringed planet at a reasonable altitude in fairly dark skies until 2020.

Through a 100mm telescope under a magnification of at least 100x, Saturn, plus its rings and numerous moons, presents a beautiful sight. Saturn's North Polar Region is tilted towards Earth at present. Its North Equatorial Belt is broad and sharply delineated against the brighter Equatorial Zone. Banding parallel to the planet's equator may be observed further north, and the North Polar Region appears dusky and well defined along its southern margin.

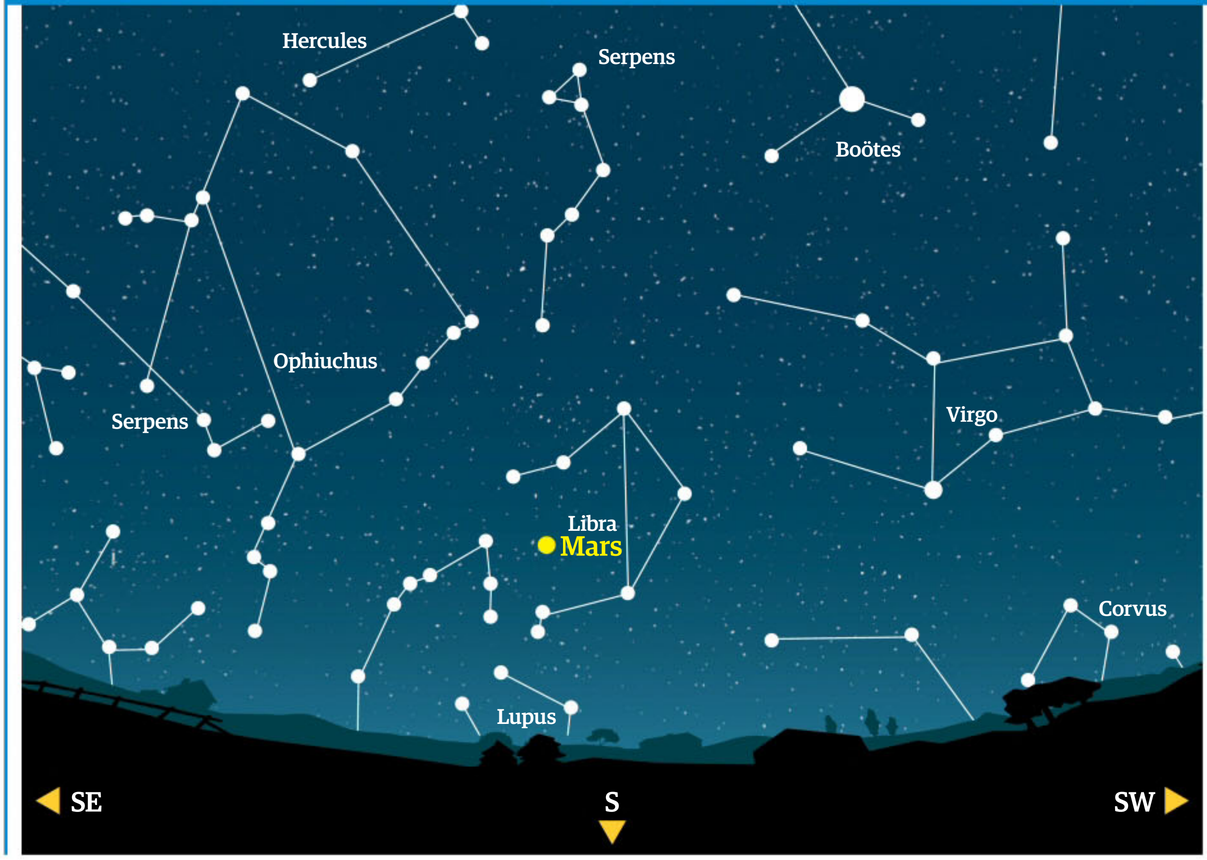
Short-lived bright spots, dark knots and irregularities in the planet's belts and zones can be seen, but they are usually pretty muted in their visual appearance. Such features are more noticeable in high-resolution CCD images, and many amateur astronomers suitably equipped with such imaging technology are capable of charting the appearance and drift of these hard-to-see phenomena. Saturn's famous ring system is wide open, and a great amount of detail within the rings may be discerned. The Cassini Division, separating the main A and B Rings, can easily be resolved under good seeing conditions, while Encke's Gap in the outer A Ring should make its presence known to users of larger instruments.

The innermost ring, the translucent C Ring (also known as the Crepe Ring) which lies inside the B Ring, should be observable to keen observers, particularly where it crosses the disc of Saturn itself, producing a narrow dusky area. Turning to Saturn's satellite system, half a dozen of the planet's moons can be discerned through the average amateur astronomer's eyepiece.

Titan, the largest and brightest of the planet's moons, shines at magnitude +8.5. It can be seen at maximum eastern elongation from the planet (three arcseconds) on the mornings of 26 June and 12 July; and can be seen at maximum western elongation on the morning of 4 and 20 July.

The brightness of Titan and its large angular separation from parent planet Saturn make it pretty easily observed through a pair of steadily mounted small (say 10x50) binoculars.

Mars 21:00 BST on 22 July

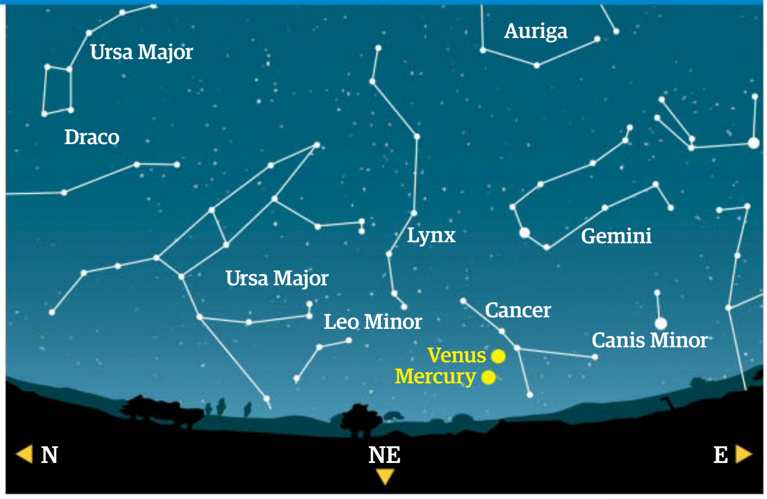


Right Ascension: 15h 31m 37s
Declination: -22° 00' 23"
Constellation: Libra
Magnitude: -1.9
Direction: South

Mars is slowly retreating from its opposition (which took place on 22 May), gradually becoming less bright in the night sky. On 23 June the Red Planet, shining at magnitude -1.9, transits the southern meridian at an altitude of 19 degrees at 10.30pm as the twilight skies are darkening. It can be followed for several hours as it sinks into the southwest. Telescopically, the planet is some 17 arcseconds across and displays a 95 per cent phase.

Under good conditions a number of prominent Martian desert features can be viewed through relatively small telescopes, despite the planet's low altitude and the astronomical twilight skies. Observational conditions, however, continue to decline and by 21 July, Mars is just five degrees above the southwestern horizon as evening twilight encroaches, presenting a magnitude -1.4 disc some 14 arcseconds across that shows a prominent gibbous phase of 89 per cent.

Mercury and Venus 07:30 BST on 21 July



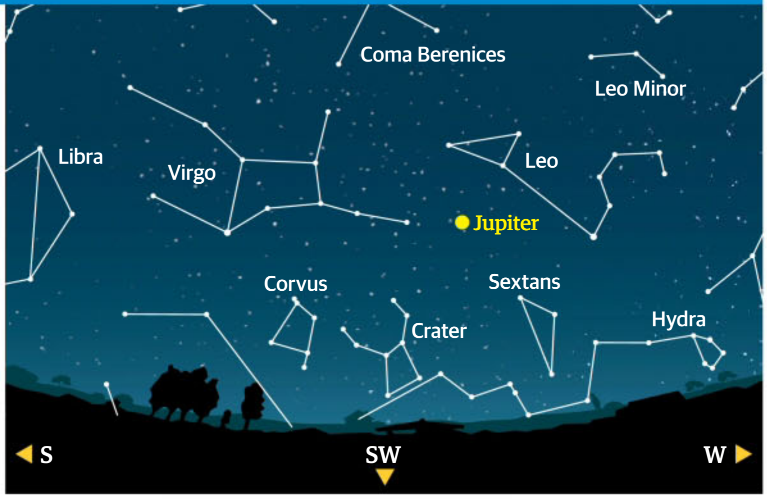
Right Ascension: 09h 04m 59s
Declination: +18° 26' 11"
Constellation: Cancer
Magnitude: -2.1
Direction: East (morning), west (evening), both unfavourable

To all intents and purposes, Mercury is highly unfavourable for observation between 23 June and 21 July, although it may just be visible before sunrise using binoculars on 23 June, when it lies 16 degrees west of the Sun, some seven degrees high at sunrise and shining at magnitude -0.9.

Right Ascension: 08h 53m 36s
Declination: +18° 54' 46"
Constellation: Gemini
Magnitude: -3.9
Direction: East (but unobservable)

Venus is virtually unobservable between 23 June and 21 July owing to its proximity to the Sun.

Jupiter 20:00 BST on 15 July



Right Ascension: 11h 21m 05s
Declination: +05° 27' 19"
Constellation: Leo
Magnitude: -1.8
Direction: West

While gas giant Jupiter continues to be an evening object throughout late June and July, it can't be seen at a decent altitude above the western horizon under anything but twilight sky conditions. On 23 June the Solar System's giant planet first becomes visible with the unaided eye at around 11.30pm, shining at magnitude -1.9 some 12 degrees above the western twilight horizon.

Observational circumstances continue to deteriorate for Jupiter, however, and by 21 July the planet is just 18 degrees above the western horizon at sunset at around 9pm, with the planet itself setting at 11pm. This more or less marks the end of a memorable Jovian apparition.

© Peta Jade; Getty Images

How to...

Make a lunar analemma

Perhaps you've heard of a solar analemma, but did you know you can get the same type of image from the Moon? Find out how...

You'll need:

- ✔ DSLR camera
- ✔ Tripod
- ✔ Wide-angle lens
- ✔ Telephoto lens

An 'analemma' is a composite picture of usually the Sun, taken over the period of a year, which shows its shifting position in the sky as the seasons progress. It can take a year to create a picture like this, so as you can imagine, it takes some dedication. However, you can create the same effect with the Moon in just 29.5 days, if you're lucky enough to have a month of clear night skies!

The image gives you an extended figure of eight pattern and can make a very attractive picture. As with the Sun, an analemma only exists as an abstract idea and as a compilation of images within one photograph, and this is the only way to see it.

The trick to creating a lunar analemma is to understand that the Moon returns to the same position in the night sky around 51 minutes later each day. Therefore, if you image the Moon around 51 minutes later each successive day over the course of one lunar month, or 29.5 days, it will trace out the figure of eight curve when the images are combined. This pattern is due to its elliptical orbit and its tilt.

You'll need a good, sturdy tripod and a way of marking its position, so that you can put it in the exact same spot each day. You'll also need some image processing software and a little skill in its use to get a good final image, especially as the thin crescent phases will need to be taken in daylight, or at least bright twilight. Use the wide-angle lens for the background shot and to get the positions of the Moon in each phase, as this will be the image upon which you will build your composite. An attractive building or mountain range can look good for the background, but remember to leave plenty of room in the sky in which to superimpose your lunar images.

The telephoto lens is used to get more detailed images of the Moon. During image processing these shots will be superimposed onto the background in exactly the right spots.

If you don't get a whole month of clear skies, you can always take a shot of the correct phase the following month and work that into your final image. Bearing this in mind, it may still take some time to build up your final analemma, but the result will certainly be worth it.

Tips & tricks

Pick your spot

You'll need to return your camera to the same spot every day, so make sure that it is easy to get to.

Use a tripod

Use a sturdy tripod to reduce camera shake, especially if there is a wind or strong breeze at your location.

Use a DSLR camera

A DSLR enables you to change the lens easily from wide-angle to telephoto.

Check the time

Make a note of the time of your first shot and add 51 minutes each successive day during the lunar month.

Use a remote shutter

Create sharper images and reduce vibration and image blurring by using a remote shutter release.

Building your composite

Create a dazzling image of the Moon's movements across the sky

Use a wide-angle lens for the background and Moon position shots and then swap to the telephoto lens or 'zoom in' and take some more detailed images of the Moon. You'll use your image processing software to superimpose these details onto the position of the Moon in your wide-angle image later on. The reason for this is to make the Moon look more 'real'. In the wide-angle shots it will seem very small and insignificant. You'll also need to vary the length of exposure to cope with the differing light conditions. Take a few images at various settings to increase your chances of getting a good shot each day.

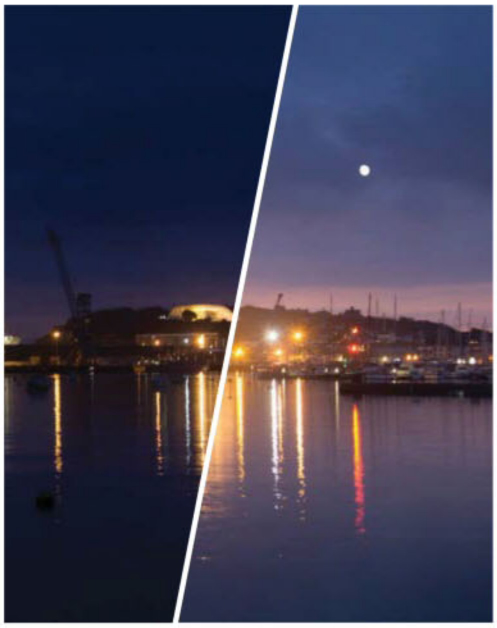
Send your photos to
photos@spaceanswers.com

1 Take a background image

Choose a good location and background for your image and take some well-composed shots. Be sure to leave plenty of sky in the images, as this will be filled with your analemma over time.

2 Keep track of the time

Keep an observation diary of the exact time of your first shot and note down the phase of the Moon each night. This will help keep track of your shots and assist while creating the composite later on.



3 Experiment with your settings

Take multiple images each night and vary the settings of the exposure time and ISO each time you photograph the Moon. This will ensure you get at least one good shot per night for your analemma.

4 Adjust your viewing time each day

Don't forget to add 51 minutes to the time of viewing for every successive day that you photograph the Moon during the lunar month. Your observation diary will help with keeping track of this.

5 Get more detail

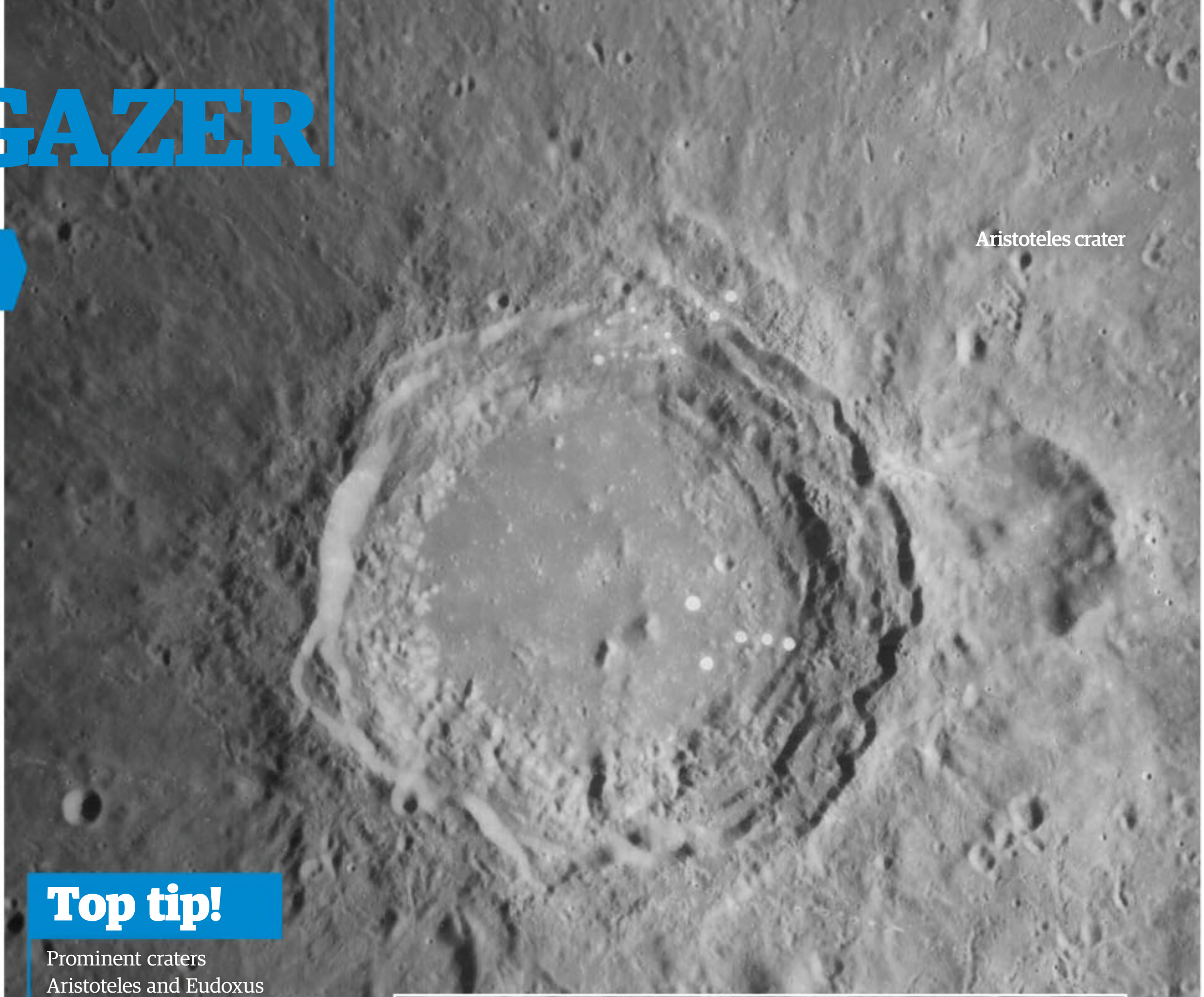
Use a telephoto or zoom lens to get more detailed images of the Moon. These details will be superimposed onto the position of the Moon in your wide-angle shot using your software later on. Don't make the lunar disc too large though.

6 Edit your images

Once you've got all of your shots across the lunar month and selected the best ones, combine all of the images into a composite using computer software such as Photoshop. This will show up the analemma.

Aristoteles, Eudoxus and Montes Caucasus

This month affords the opportunity to observe two of the Moon's most prominent craters and mountain ranges


Aristoteles crater

This month we turn our attention away from foreshortened lunar maria arrayed near the Moon's eastern edge to look at a notable visual partnership - one that's easily viewed through virtually any optical equipment. It involves two very prominent craters and a majestic mountain range that runs from north to south across several hundred kilometres of the Moon's upper northeastern quadrant, between the latitudes of 50 degrees and 30 degrees north.

Prominent craters Aristoteles (84 kilometres, or 52 miles) and Eudoxus (64 kilometres, or 40 miles) form a striking duo when seen through any telescope, particularly when they are illuminated by an early morning or late evening Sun. Indeed, the crater pair can be spotted whenever they are illuminated by the Sun - even through binoculars at full Moon - since both take the form of bright, well-defined rings when viewed under a high illumination.

Aristoteles, the larger and more impressive of the pair, has a slightly polygonal outline, along with broad inner walls that display some of the most extensive terracing within any lunar crater. Its floor is depressed below the mean level of the surrounding terrain, forming a flattish base around 40 kilometres (25 miles) in diameter, with two small mountain peaks protruding from the southern portion - features that are easily visible under the right illumination conditions using a relatively small telescope (under 60mm).

Aristoteles' rim is clear cut, displaying a scalloped effect that's seen in many other large impact craters of a similar size; such an effect is caused by large units of rock that have broken away from the crater wall and slid down it to some extent. Under a morning or evening illumination, a broad range of impact structuring can be discerned in Aristoteles' vicinity, taking the form of a mass of radial ridges that extend out from the rim for tens of kilometres. Buried within this structure on the crater's eastern wall is Mitchell (30 kilometres, or 19 miles), a crater that predates Aristoteles, providing a good example of a smaller crater that is overlapped by a larger crater.

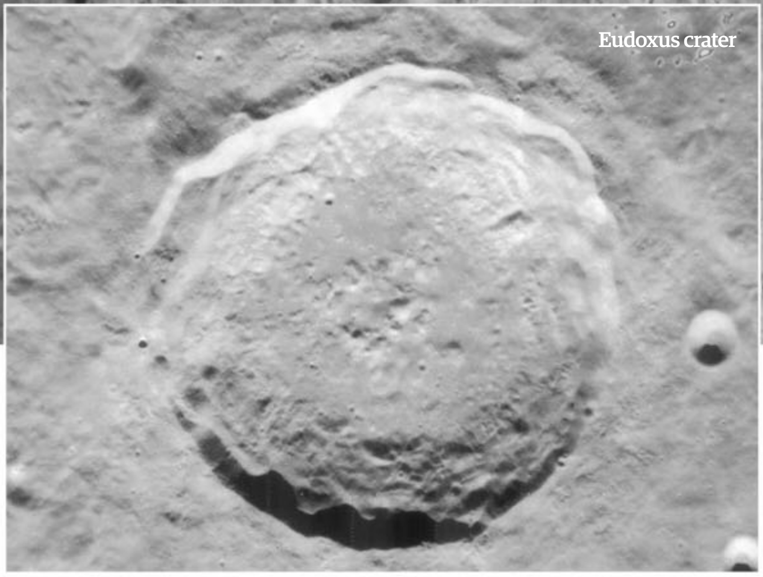
South of Aristoteles the terrain becomes much rougher. At 100 kilometres (62 miles) to the south, Eudoxus makes an interesting neighbour - both Aristoteles and Eudoxus are easily encompassed within the field of view of a high magnification eyepiece. Although it superficially resembles Aristoteles, close examination of Eudoxus will show a number of differences. Eudoxus' internal terracing is less ordered and its floor is somewhat blockier. The impact structuring around Eudoxus is less grand, partly because of the rougher nature of the surrounding terrain, with more concentric rather than radial structures being evident.

Aristoteles and Eudoxus are the bright jewels in a handle holding the south-pointing, highly-serrated 'dagger' of Montes Caucasus (Caucasus Mountains). This is an impressive mountain range that makes a north-south wedge more than 500 kilometres (311 miles) long, and separates eastern Mare Imbrium from northwestern Mare Serenitatis. Peaks in the range reach heights of 6,000 metres (19,685 feet) in places. The mountain range appears particularly prominent when illuminated by (roughly) a first or last quarter Moon.

This month, the best opportunity to view Aristoteles, Eudoxus and Montes Caucasus is on the mornings of 25 and 26 June (evening illumination) and 11 July (morning illumination), the latter date being by far the most amenable for telescopic observation.

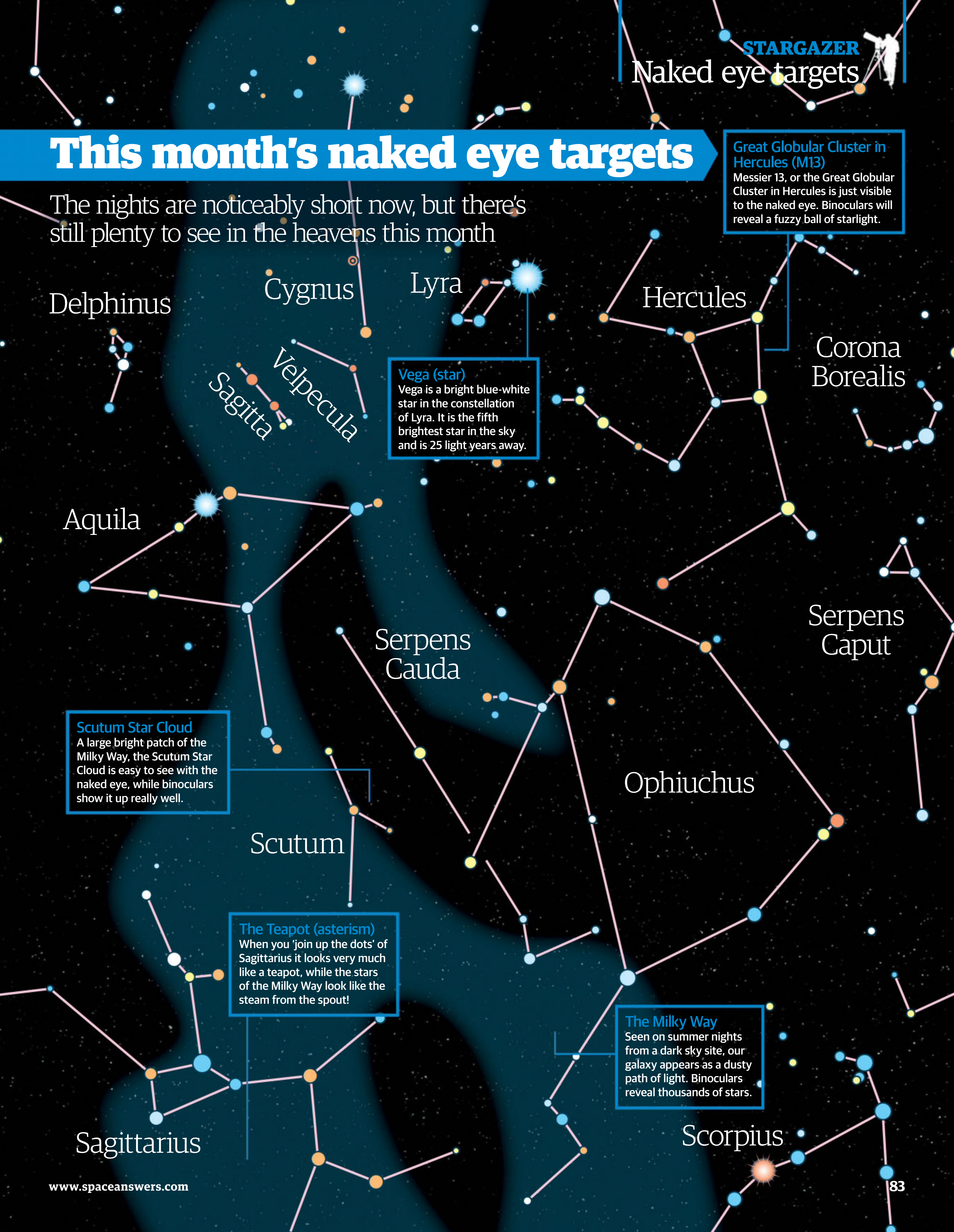
Top tip!

Prominent craters Aristoteles and Eudoxus form a striking duo when observed through a telescope, particularly when an early morning or late evening Sun illuminates them. A Moon filter will improve contrast, toning down any glare that often washes out intricate features of the lunar surface.


Eudoxus crater

This month's naked eye targets

The nights are noticeably short now, but there's still plenty to see in the heavens this month



Great Globular Cluster in Hercules (M13)
Messier 13, or the Great Globular Cluster in Hercules is just visible to the naked eye. Binoculars will reveal a fuzzy ball of starlight.

Vega (star)
Vega is a bright blue-white star in the constellation of Lyra. It is the fifth brightest star in the sky and is 25 light years away.

Scutum Star Cloud
A large bright patch of the Milky Way, the Scutum Star Cloud is easy to see with the naked eye, while binoculars show it up really well.

The Teapot (asterism)
When you 'join up the dots' of Sagittarius it looks very much like a teapot, while the stars of the Milky Way look like the steam from the spout!

The Milky Way
Seen on summer nights from a dark sky site, our galaxy appears as a dusty path of light. Binoculars reveal thousands of stars.

How to...

@Getty Images; Jon Hicks

Get the best views of Pluto

On 7 July the dwarf planet reaches opposition. This is the best time to see it if you have the right equipment...

You'll need:

- ✔ Large telescope
- ✔ Star chart
- ✔ DSLR or CCD camera

When a planet is said to be in 'opposition', it means that it is directly opposite the Sun in our skies and is therefore usually available to view all night long. It also means that it will be about as near to Earth as it can get in terms of our respective orbits.

In the case of tiny Pluto, this opposition occurs in the constellation of Sagittarius. Because Pluto is so small and distant, you'll need a large aperture telescope - in this case at least 16 inches or 400mm in aperture - to have any real chance of spotting it in the sky. In fact, the larger the aperture, the better your view will be!

Photography can make matters easier and so the use of a DSLR or dedicated astronomical CCD camera attached to your telescope can show the dwarf planet up relatively easily. If you're planning to observe Pluto visually, you'll need a good star chart or a reliable 'GoTo' computer control for your telescope's mount. Even then, a good star chart printed out for the area required will help confirm that you're actually looking at Pluto.

To make things a little more challenging for observers in mid-northern latitudes, Pluto will be quite low in the sky, barely getting above 18 degrees above the horizon at its highest point. Observers in more southerly latitudes will have an easier time of it. Even in a large telescope though, Pluto will look like a faint star. The fun of observing this distant planet lies in the fact that you can see such a tiny, remote world at all.

Pluto will be quite close to the star Pi Sagittarii, known as Albaldah, and will be just over 15 arcminutes due west of the star, which is part of the chain of stars that make up the Archer's Cape. This star is shining at magnitude +2.85, so it is relatively bright when compared to the +14.3 magnitude of Pluto! Once you think you're in the right area, increase the magnification to improve the contrast.

One way to be sure that you're seeing Pluto is to take an image of the star field that it is in every night for three or four nights in a row. The small star that appears to move position slightly, compared to all the other stars that appear fixed, is the dwarf planet.

Not many people have seen Pluto, so it's definitely worth the challenge. You'll have several nights either side of opposition where it will remain relatively bright, so get out there and see if you can spot it. Happy hunting!

Tips & tricks

A large aperture is best

The bigger the aperture of your telescope, the better. With Pluto, light-gathering power is paramount.

Print out a star chart

You'll need a chart that can show stars down to magnitude 15. It's best to print one out.

DSLR camera

Use a DSLR camera connected to your telescope to image the star field.

Test the GoTo

If you're using a 'GoTo' computer control, ensure it is set up correctly by testing it on a bright star near to Pluto.

Use low power eyepieces

Check you're in the right area of sky using a low power eyepiece. Move up the magnification once you're there.

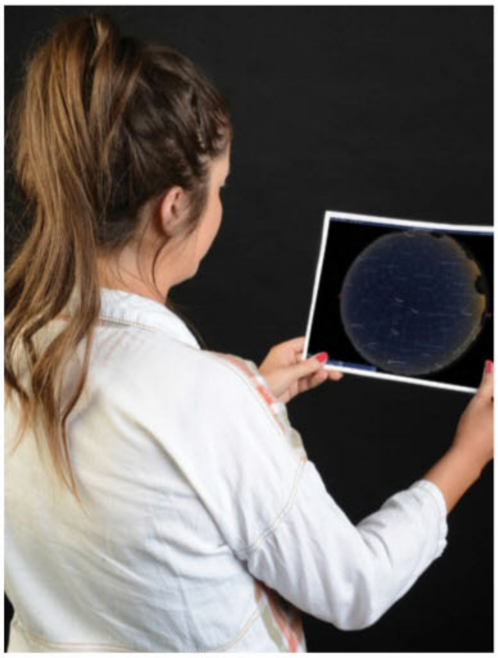
Hunting for a dwarf planet

Increase your chances of spotting this tiny, remote world

Pluto is really very faint and will test your observing skills. If you're viewing it through an eyepiece, make sure your eyes are really dark-adapted. Fortunately, the Moon won't be a problem at this time as it will have set by the time it is dark enough to observe.

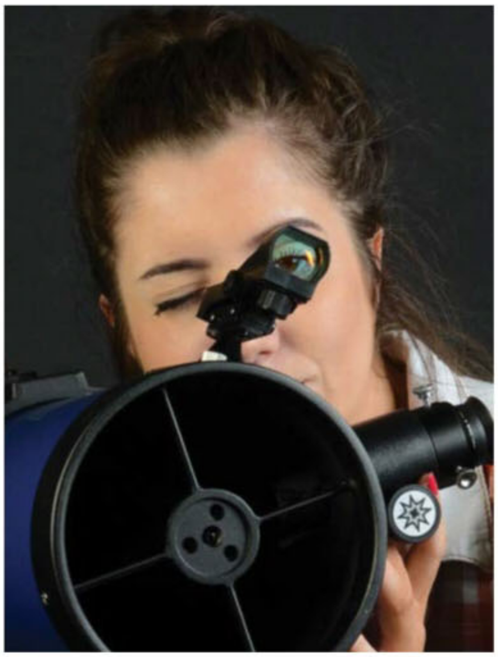
Print out a star chart for the area of sky where Pluto is and make sure it shows enough stars to help you get your bearings. This will be helpful, too, if you are imaging the area. Do this over several nights if you can. The moving 'dot' in the image will be Pluto.

Send your photos to
photos@spaceanswers.com



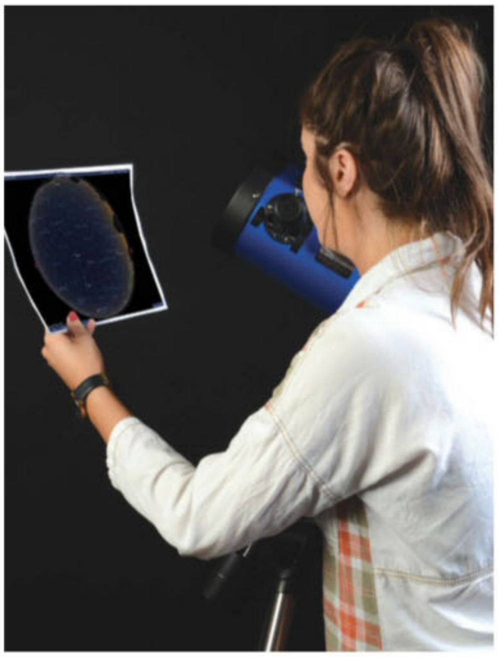
1 Print out a star chart

Print out a star chart from your favourite planetarium software to show the relevant area of sky from your location.



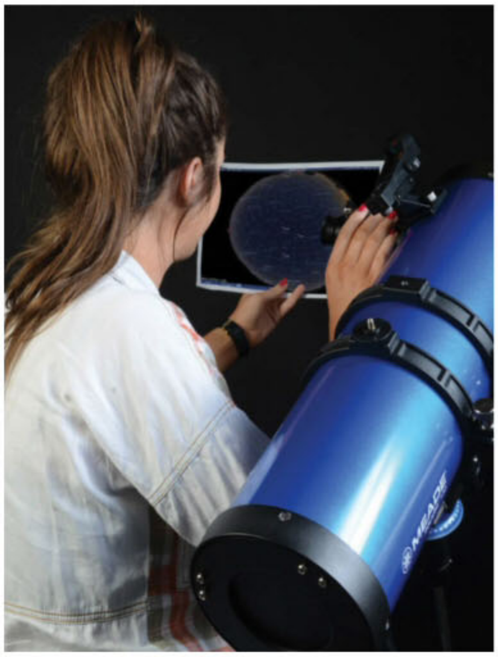
2 Find Pi Sagittarii

Using your finder scope or 'GoTo' computer control, find the star Pi Sagittarii or 'Albaldah' in the Archer's Cape of Sagittarius.



3 Get your bearings

Once you have found Pi Sagittarii, check the star chart and try to relate it to what you're seeing through your telescope in order to get your bearings.



4 Go west!

Slowly guide your telescope westward, continually checking your star chart until you think you can see Pluto in the field of view.

5 Take your time

Don't rush! Take your time and study the view closely. If you can't see Pluto directly, then try using averted vision in order to spot it.

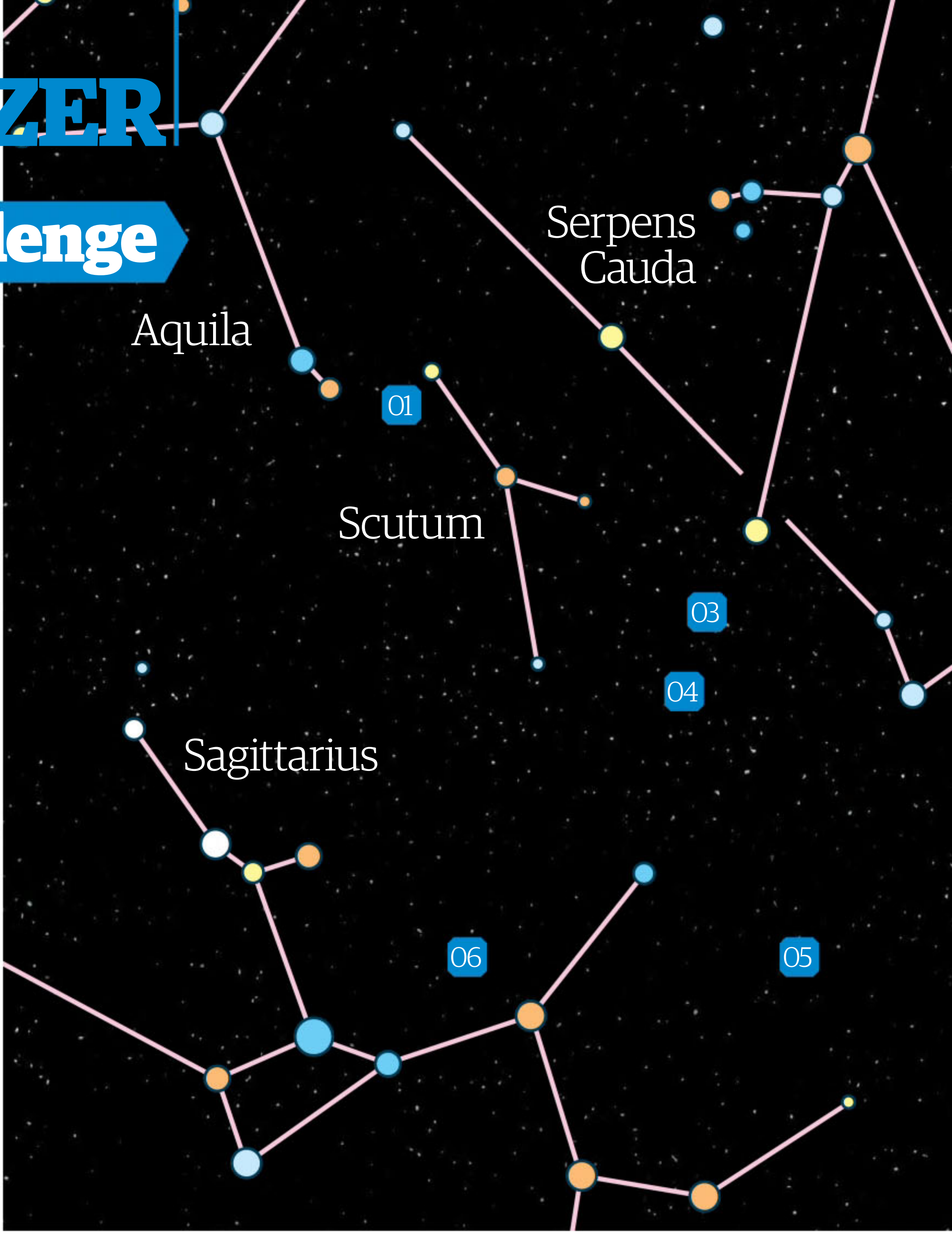
6 Start imaging Pluto

If you're using a DSLR or CCD camera on your telescope, use a fairly high ISO and take an image each night for several nights if possible.

Deep sky challenge

Nebulae and clusters of the summer

The nights are still short, but there are plenty of things to see if you stay up late



It's well worth staying up late at this time of year, as some of the best and most spectacular targets for your telescope are well positioned in the night sky. For example, there's one of the best globular clusters in the entire night sky, as well as nebulae and open star clusters. The Milky Way sits on a line almost north to south and some of the best objects can be found in the southern section, which you can go hunting for with your telescope.

No matter what the size of your telescope, there will be some wondrous sights to see. Some of these objects are quite low down near the southern horizon, so try to find an observing spot that provides a good view in this direction with few trees or buildings along the horizon. Given that the nights in the Northern Hemisphere are usually relatively warm, there are plenty of reasons to get outside with your telescope and enjoy what the universe has to offer. Here are some of the best objects to view...

1 **The Wild Duck Cluster (M11)**
Taking its name from the 'V' shaped pattern of stars that looks like a flight of wild ducks, a small telescope will show Messier 11 well.

2 **Globular Star Cluster M10**
This tight globular star cluster is a target for telescopes of all sizes. Larger instruments should reveal many of the stars in the group.

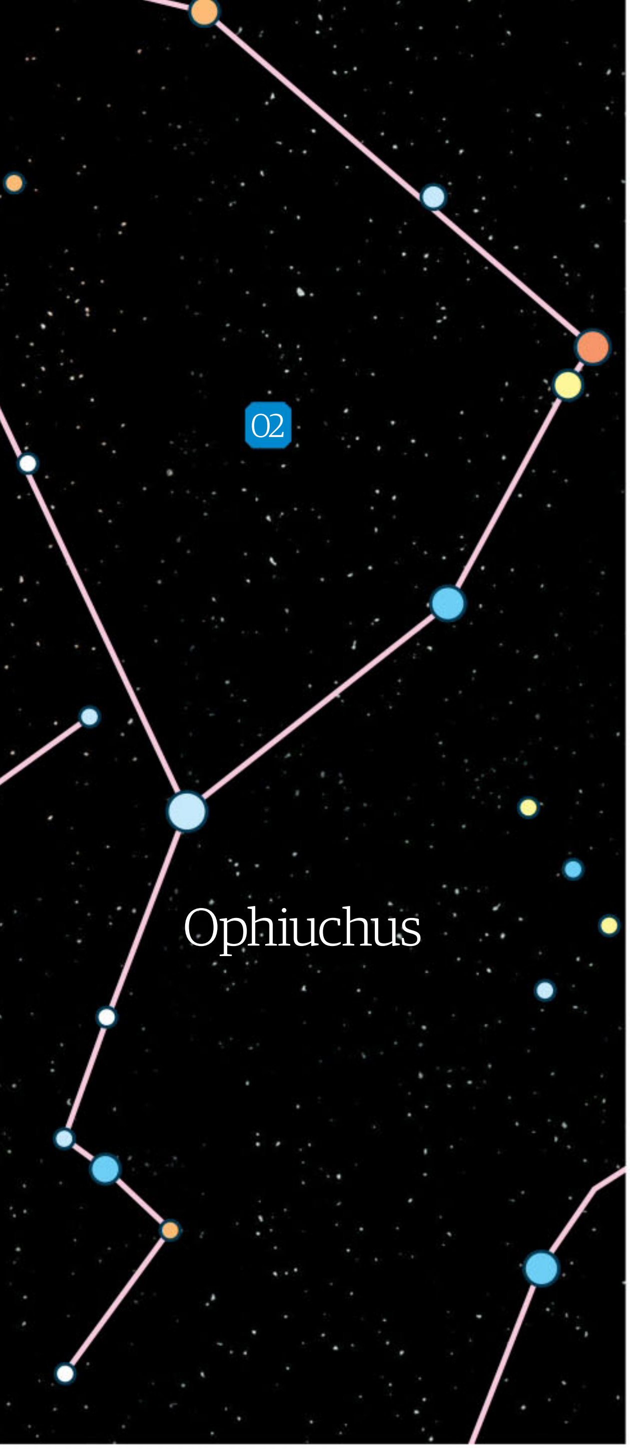
3 **The Eagle Nebula (M16)**
Made famous by the Hubble Space Telescope, this is a more challenging object. A larger telescope should show some detail.

4 **The Omega Nebula (M17)**
This object has a distinct U-shape, so it's sometimes known as the Horseshoe Nebula. It is a huge cloud of hydrogen gas.

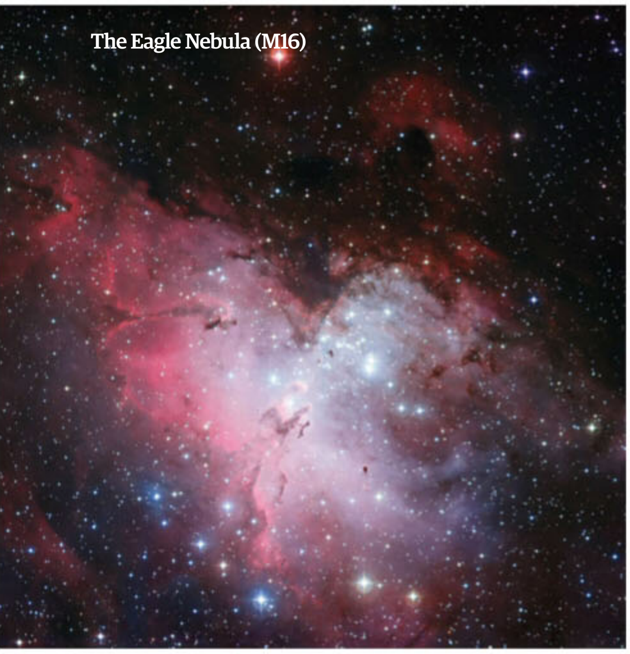
5 **The Trifid Nebula (M20)**
The three dark dust lanes emanating from its centre give this nebula its name. It looks quite peculiar through a small telescope.

6 **Globular Star Cluster M22**
Due to its low declination, this bright globular star cluster appears fainter than it usually does. A moderate telescope should discern many of its stars and its bright core.

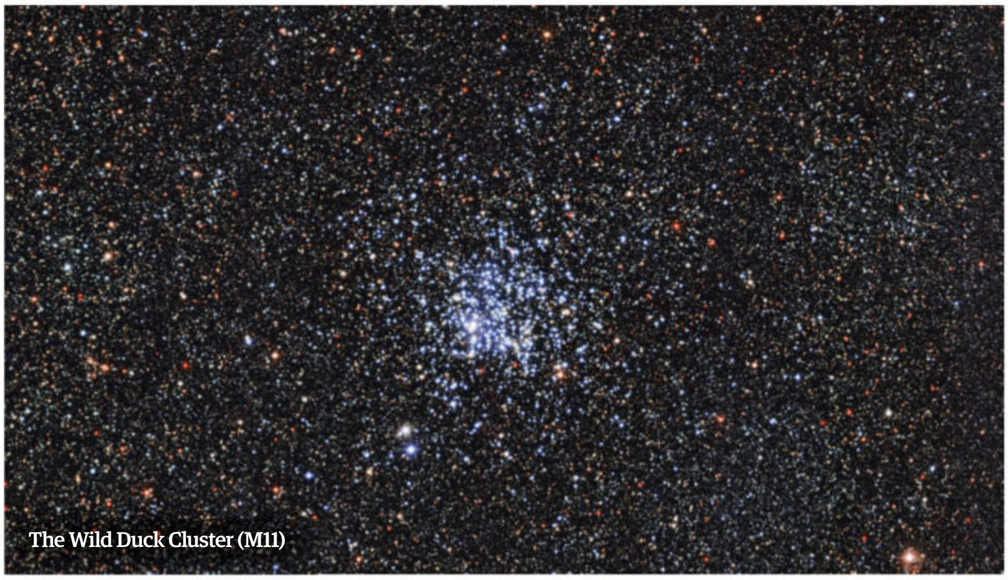
The Omega Nebula (M17)



The Trifid Nebula (M20)



The Eagle Nebula (M16)



The Wild Duck Cluster (M11)

© ESO; NASA

The Northern Hemisphere

Now well into summer, nebulae are visible and the central part of our galaxy is teeming with star clusters to enjoy

The short warmer nights offer a splendid selection of nebulae, star clusters and bright stars to observe. Red supergiant Arcturus proudly makes its appearance known in the constellation of Boötes.

The unmistakable Summer Triangle is easily observed this month, with the stars Altair, Deneb and Vega in the constellations of Aquila, Cygnus and Lyra respectively marking each of its corners. The summer is an ideal time to see the Milky Way galaxy, with Sagittarius and Scorpius marking its centre – here you'll see a selection of clusters including the Ptolemy Cluster, also known as Messier 7.

To add to an impressive night-time display, the naked-eye planets make their way along the ecliptic at varying times of the evening and into dawn. You should use a red torch to preserve your dark-adapted vision when using this map.

Using the sky chart

This chart is for use at 10pm (BST) mid-month and is set for 52° latitude.

01 Hold the chart above your head with the bottom of the page in front of you.

02 Face south and notice that north on the chart is behind you.

03 The constellations on the chart should now match what you see in the sky.

Magnitudes

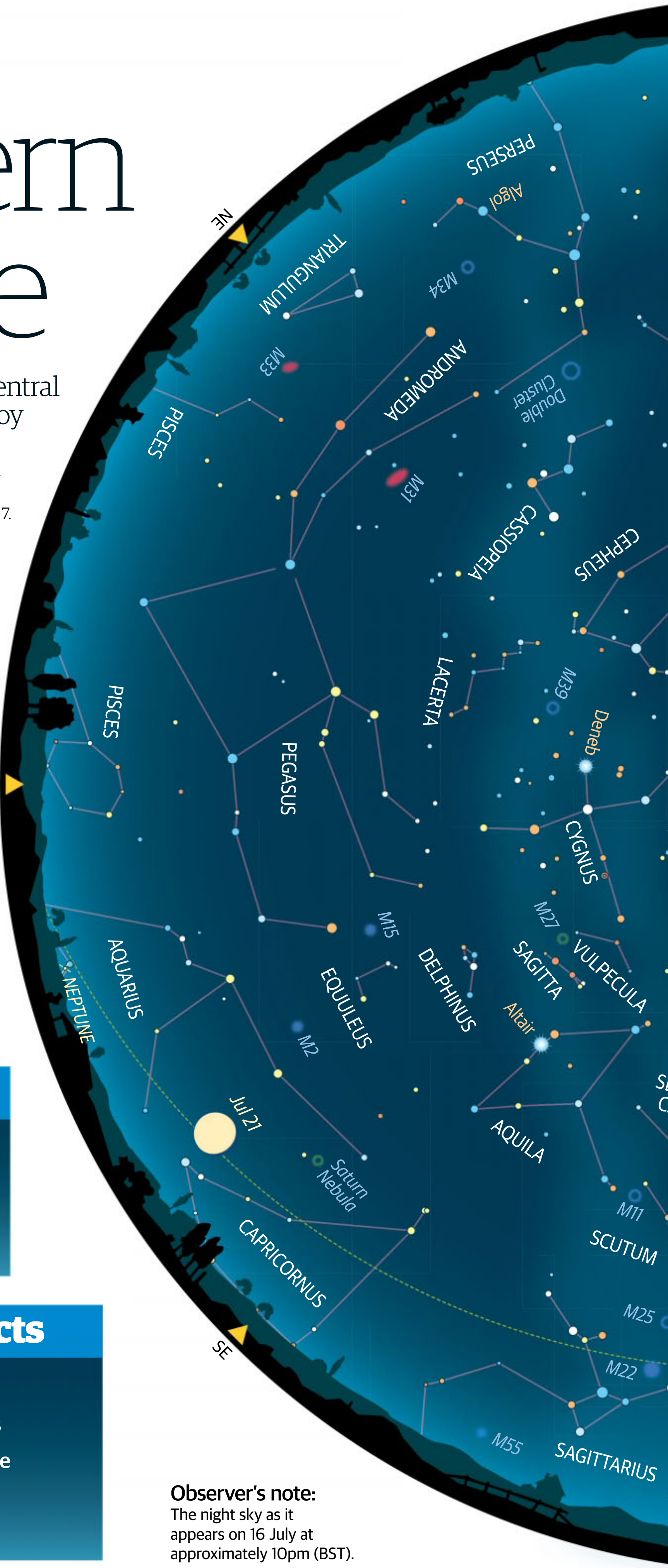
- ● Sirius (-1.4)
- ● -0.5 to 0.0
- ● 0.0 to 0.5
- ● 0.5 to 1.0
- ● 1.0 to 1.5
- ● 1.5 to 2.0
- • 2.0 to 2.5
- • 2.5 to 3.0
- • 3.0 to 3.5
- · 3.5 to 4.0
- · 4.0 to 4.5
- · Fainter
- ◉ Variable star

Spectral types

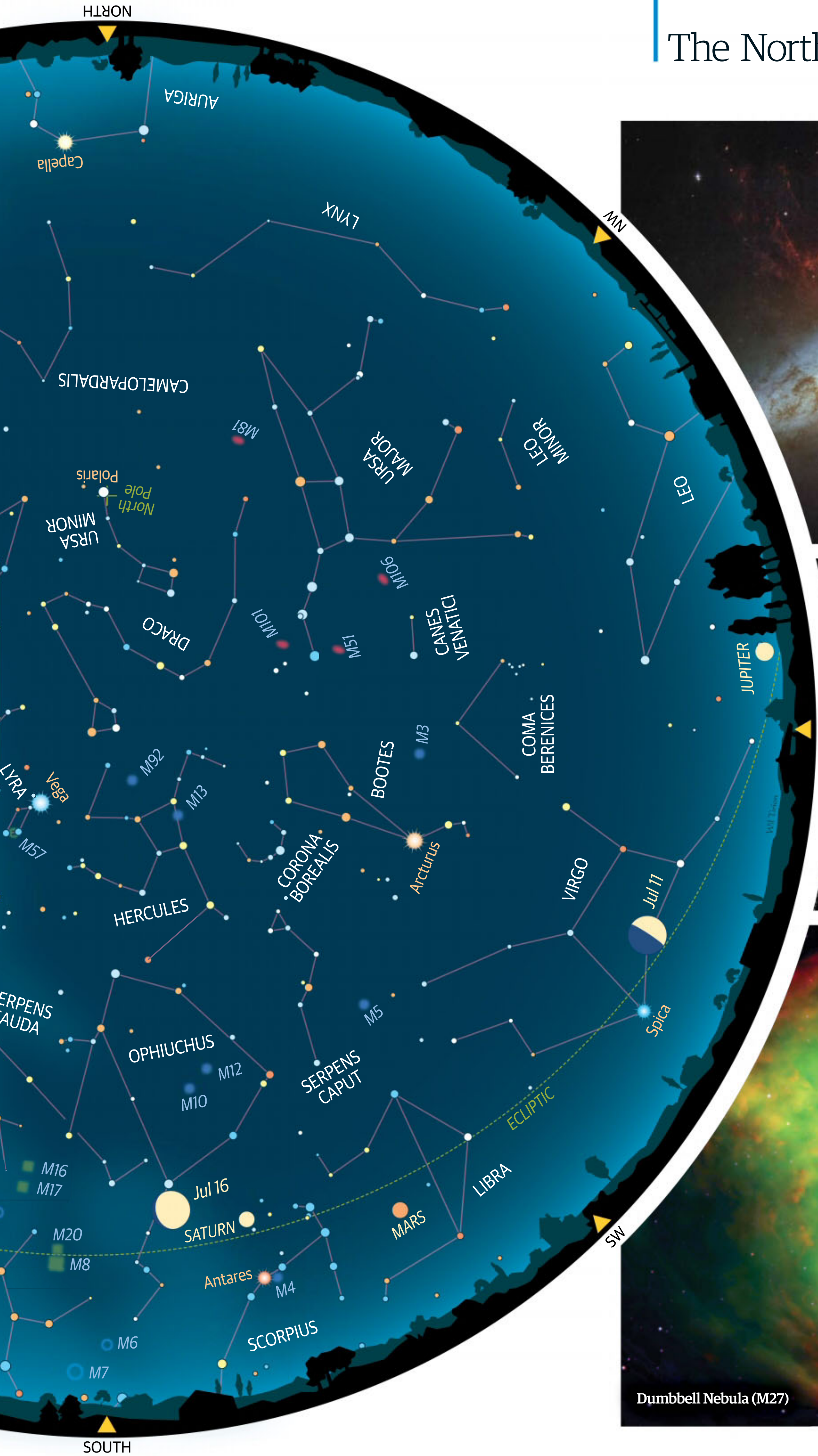
● O-B ● G
● A ● K
● F ● M

Deep-sky objects

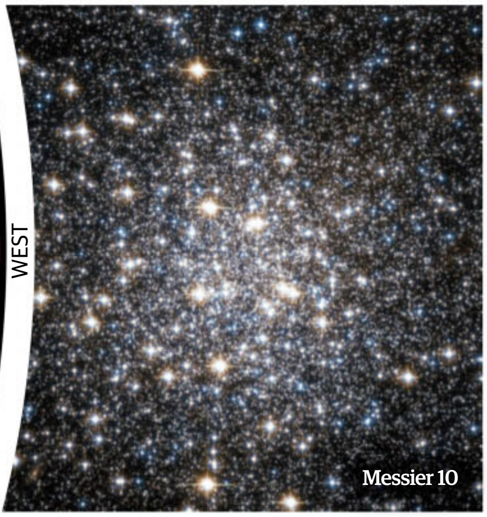
- ○ Open star clusters
- ● Globular star clusters
- ■ Bright diffuse nebulae
- ◎ Planetary nebulae
- ⬮ Galaxies

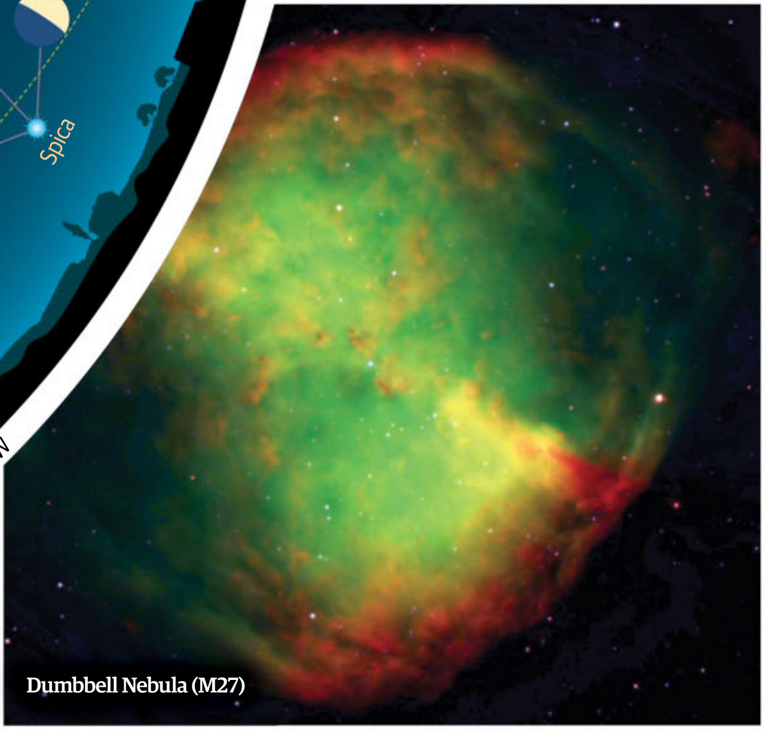


Observer's note:
The night sky as it appears on 16 July at approximately 10pm (BST).



Cigar Galaxy (M82)


Messier 10


Dumbbell Nebula (M27)

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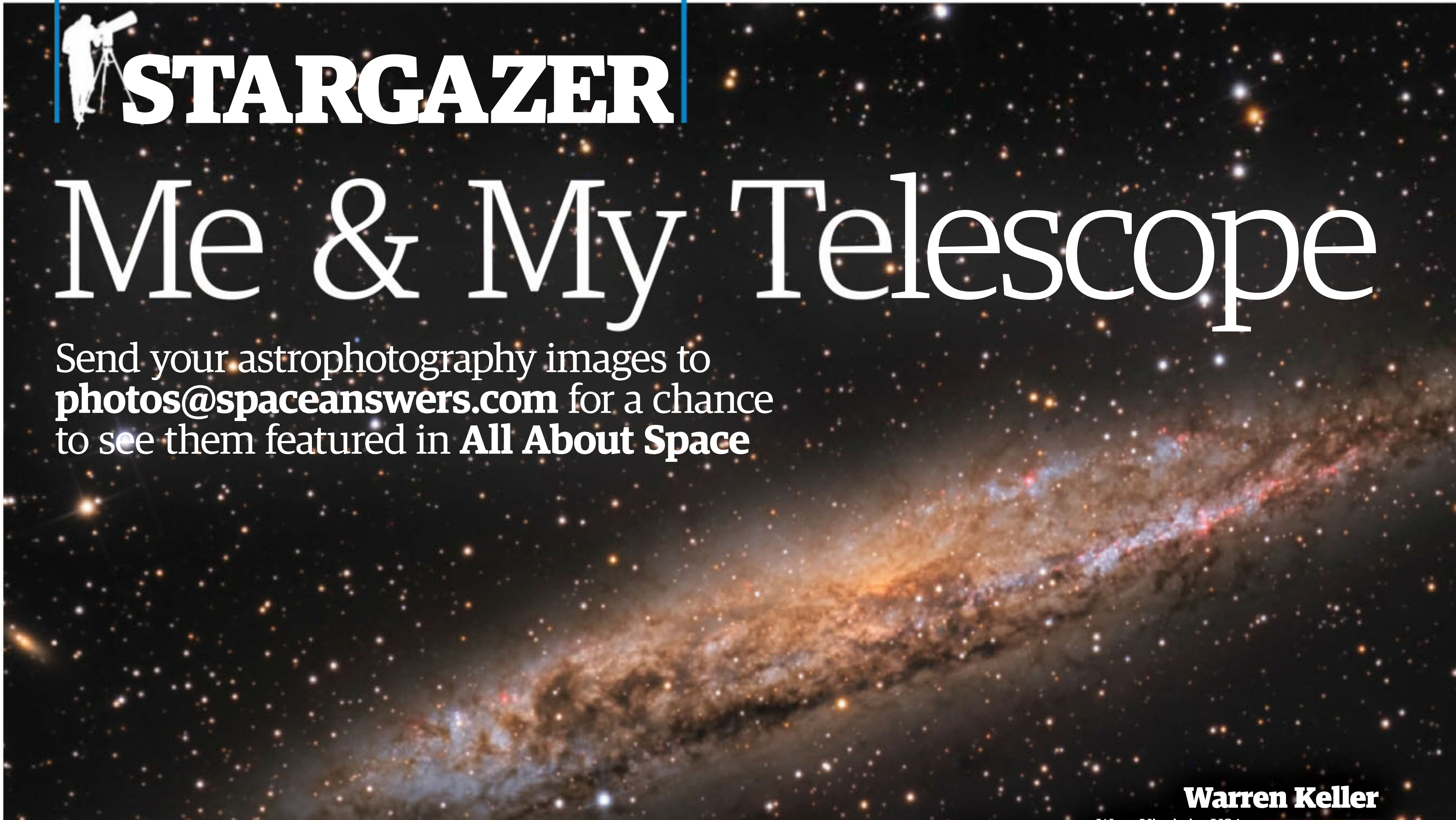
Me & My Telescope

Send your astrophotography images to **photos@spaceanswers.com** for a chance to see them featured in **All About Space**



Spiral galaxy NGC 4945

Warren Keller

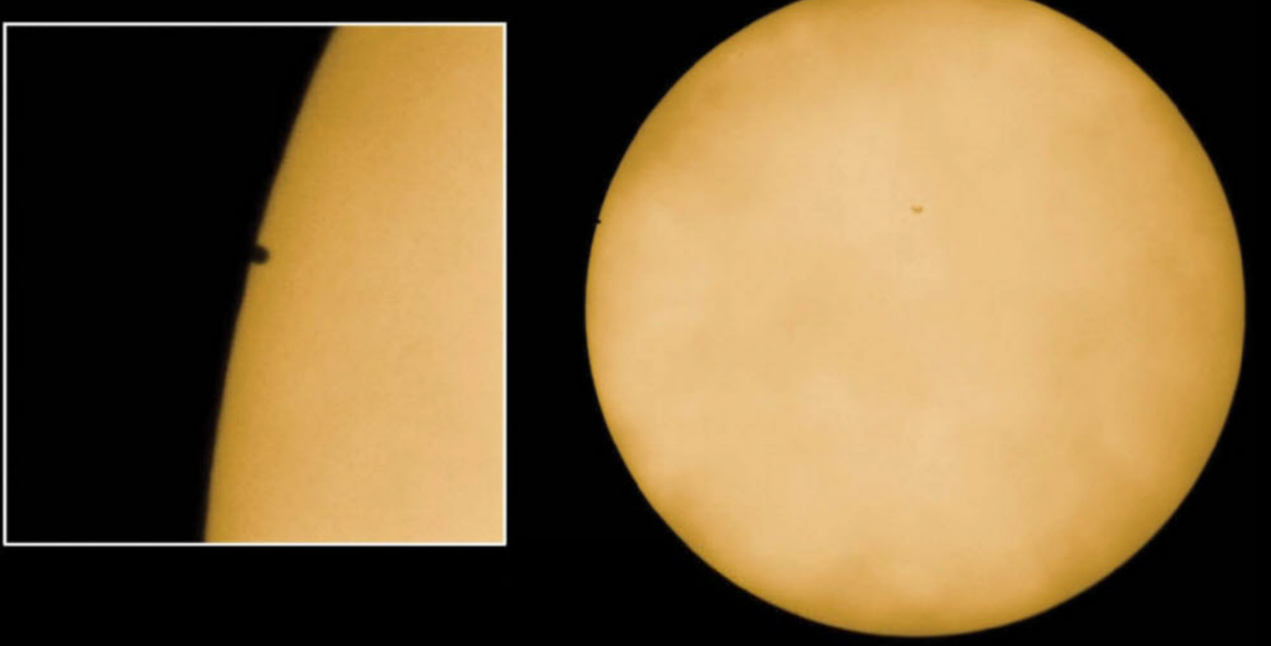
West Virginia, USA
Telescope: 16" RCOS Ritchey-Chrétien (University of North Carolina owned)

"I began exploring the night sky at the age of 15 with an 8-inch Newtonian during the 1960s. It wasn't until 1998 that I got my first taste of astroimaging with film, and a few years later I switched to a charged-coupled device in order to capture the treasures of the night sky. For me, the thrill of the hunt for the beautiful shapes and colours of the universe is more appealing than the cosmology side of it. And my astrophotography tutorial business has given thousands of people a quick start to taking their own great photos."

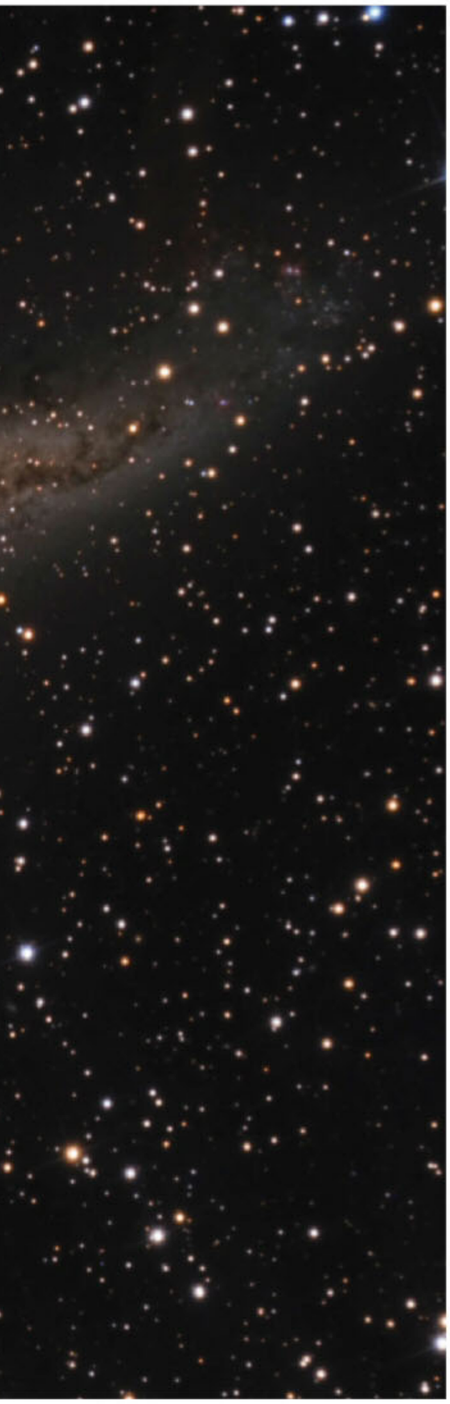
Zlatko Orbanic

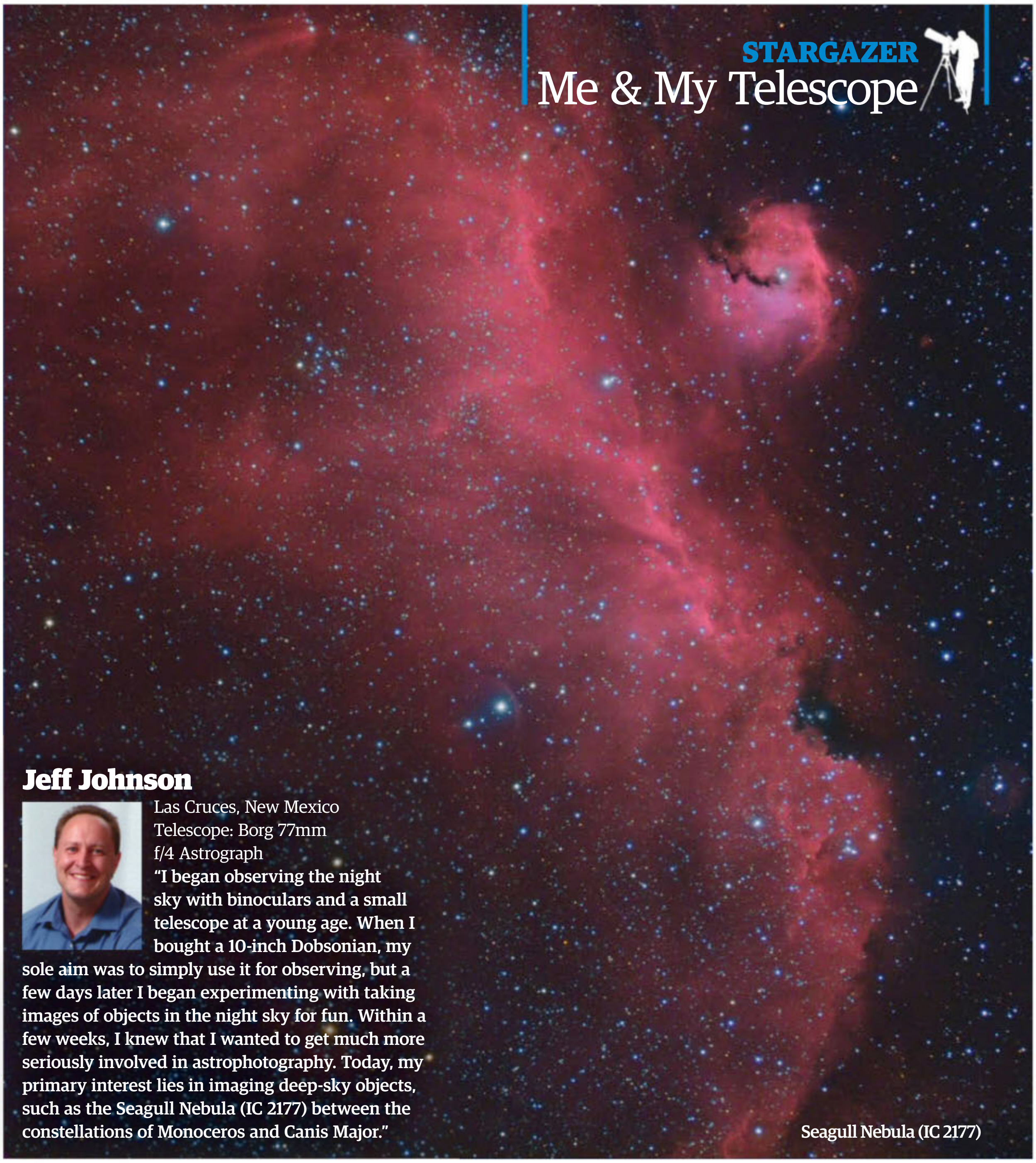
Pula, Croatia
Telescope: Vixen ED 102/660 Apochromatic Refractor

"My astronomy hobby began several years ago, and ever since then I have wondered how big space is when I look up at the very distant stars. I am a keen astronomer and often wake up at night to observe the night sky until the crack of dawn. Astronomy can often be hard work and I sometimes wonder what possesses me to have a hobby like this when I'm looking through my telescope during the very cold evenings. However, as there's so much to discover in the night sky, no matter what time you are observing, it is all definitely worthwhile."



Transit of Mercury, May 2016



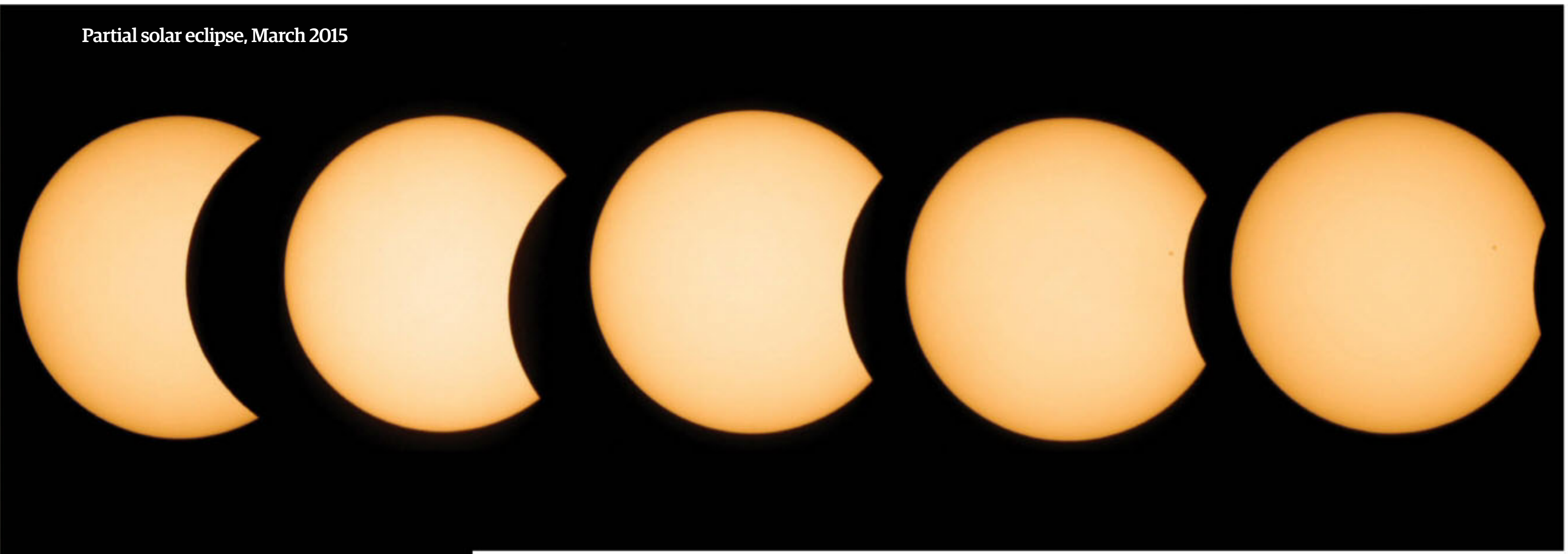


Jeff Johnson

Las Cruces, New Mexico
Telescope: Borg 77mm f/4 Astrograph

"I began observing the night sky with binoculars and a small telescope at a young age. When I bought a 10-inch Dobsonian, my sole aim was to simply use it for observing, but a few days later I began experimenting with taking images of objects in the night sky for fun. Within a few weeks, I knew that I wanted to get much more seriously involved in astrophotography. Today, my primary interest lies in imaging deep-sky objects, such as the Seagull Nebula (IC 2177) between the constellations of Monoceros and Canis Major."

Seagull Nebula (IC 2177)



Partial solar eclipse, March 2015

Send your photos to... @spaceanswers photos@spaceanswers.com

Omegon MightyMak 90

Highly portable, simple to use and ideal for beginners on a budget, this small telescope is an excellent introduction to astronomy

Telescope advice

Cost: €215 (approx. £170)
From: Astroshop.eu
Type: Maksutov-Cassegrain
Aperture: 3.54"
Focal length: 39.37"

Best for...

- Beginners
- Small budget
- Planetary viewing
- Lunar viewing
- Terrestrial viewing
- Basic astrophotography

If you're looking for a telescope that's easy to carry and set up for your very first venture into observing, or perhaps you have children that have been hassling you for a scope but you don't want to spend a fortune on a hobby that could end up being a fad, then the Omegon MightyMak 90 is a worthwhile option to consider.

Omegon's affordable product provides two types of mount – a tabletop tripod and a Dobsonian, ideal for quick wildlife watching and night sky viewing – as well as a Kellner 25mm eyepiece and a handy transport bag. Unusually, however, there doesn't seem to be a finderscope or red dot finder to assist with finding objects, something that may hinder a novice astronomer's observing sessions to a large degree. For the purpose of this review, we attached an in-house red dot finder to the telescope in order to test it sufficiently.

Overall, the MightyMak 90 is very well built; the tube in particular is of superb quality. The build of the Dobsonian mount is good, but the tabletop tripod doesn't seem to support the tube as well without severely tightening the tripod pan handle. The MightyMak 90 is sufficiently packaged in bubble wrap to ensure safe transportation. The flip-flop dust cap, which is fixed to the telescope's objective lens, is a nice touch, ensuring that you don't lose this important accessory, although it could be a hindrance while observing, particularly on a windy evening.

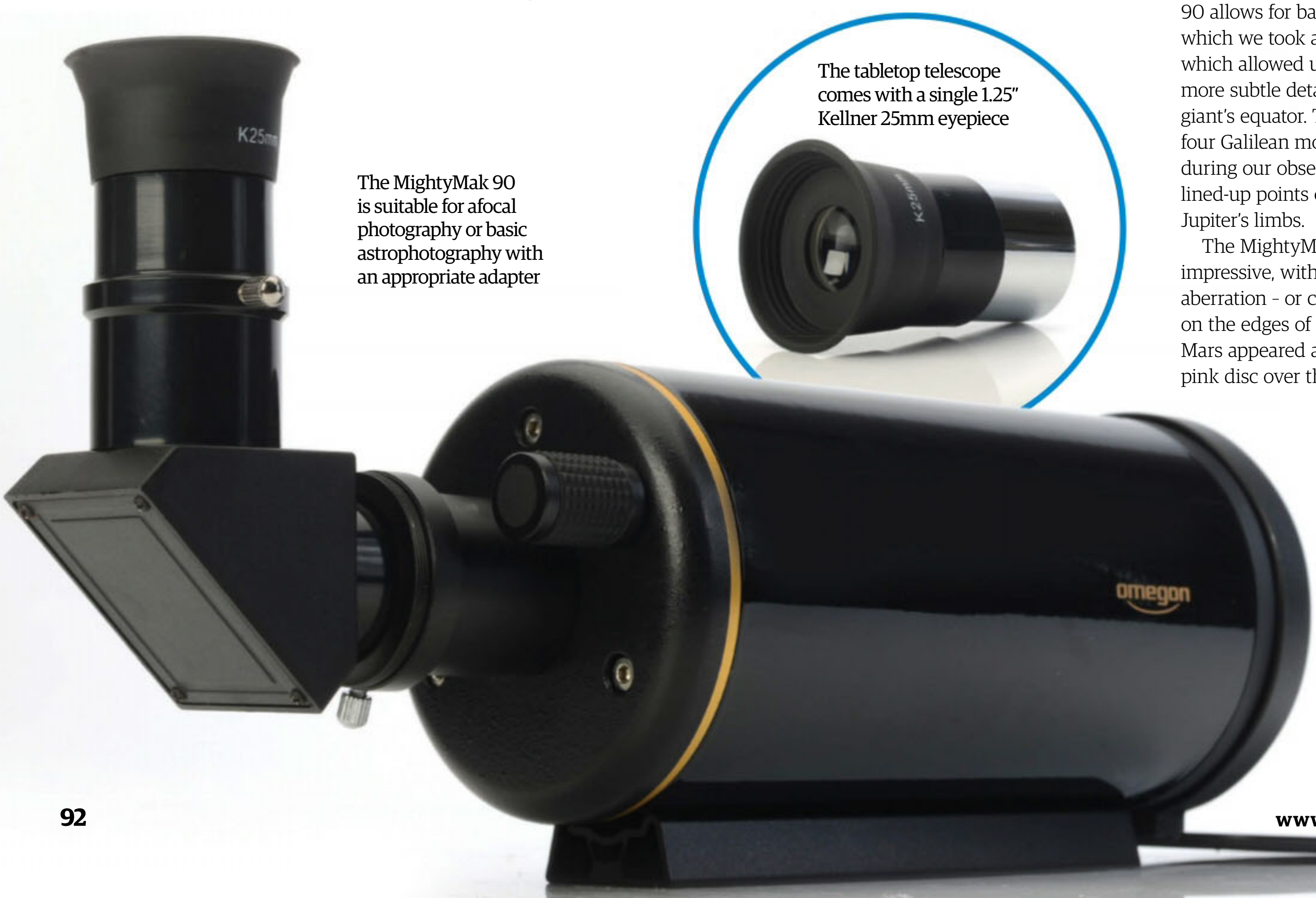
We selected the sturdier Dobsonian mount for our observations. Setting the telescope up was a breeze and within moments we got stuck into targeting a selection of objects.

"The Omegon MightyMak 90 is versatile and suits a wide range of eyepieces and filters"

With its small aperture, the MightyMak 90 is only really suitable for observing Solar System targets and the surface of the Moon – highly recommended targets for those just starting to observe the night sky. Slewing from one region of the sky to the other, we enjoyed the smooth operation, while still giving just the right amount of resistance for stability when observing chosen targets. With Saturn and Mars recently reaching opposition, we quickly located the pair as yellowish and red stars not too far apart from each other in the constellations of Ophiuchus and Libra respectively, while Jupiter proudly shone as a bright point in the constellation of Leo.

We made Jupiter our first target, which appeared as a bright disc. By using averted vision, we could make out two of its prominent bands – an impressive feat given the small aperture of this scope. The MightyMak 90 allows for basic astrophotography, which we took advantage of, and which allowed us to reveal much more subtle detail across the gas giant's equator. Three of the planet's four Galilean moons were visible during our observations, appearing as lined-up points of light either side of Jupiter's limbs.

The MightyMak 90's clarity is impressive, with no chromatic aberration – or colour fringing – visible on the edges of any bright objects. Mars appeared as a small, salmon-pink disc over the southern horizon,



The tabletop telescope comes with a single 1.25" Kellner 25mm eyepiece

The MightyMak 90 is suitable for afocal photography or basic astrophotography with an appropriate adapter

The Maksutov's tube doesn't feel sufficiently supported by the 'wildlife watching' tripod

Sadly, the MightyMak 90 is not supplied with a red dot finder or finderscope to assist with navigation

The telescope tube employs a Maksutov-Cassegrain design for exquisite views of Solar System targets

The Dobsonian mount provides a suitable, sturdy option for observing planets and the lunar surface

while the ringed giant stole the show at magnitude +0.8. While the view of Saturn was small in the field of view, the planet's majestic rings blew us away. Although conditions weren't favourable enough to pick out the Cassini Division without the aid of photography equipment, the MightyMak 90 surpassed expectations. The manual to the Maksutov-Cassegrain states that the scope isn't very useful in observing deep-sky objects. While on the whole, this is true of this desktop scope, it is capable of picking out rich star clusters as well as bright nebulae.

The MightyMak 90 is a very good telescope for those wanting to get into astronomy without breaking the bank, and the scope also doubles up for terrestrial viewing, adding more bang for your buck. Although the setup came without a finderscope and could have been supplied with a few more accessories, the MightyMak is versatile and suits a wide range of eyepieces and filters. There are cheaper scopes on the market of a more substantial size, but this 'pint-sized' model has an advantage thanks to its portability.

WIN

A VIXEN POLARIE STAR TRACKER

WORTH OVER £600!

Courtesy of Opticron, we're giving away kit to assist with your astrophotography this month

A compact mount platform that allows you to capture nightscapes and star images with elegance and ease, the Vixen Polarie Star Tracker allows you to capture the universe through the art of astrophotography.

Ultra-light and portable, this star tracker is ideal for wide-field astroimaging. Operational on two AA batteries, the Polarie tracks the motion of the stars in order to eliminate star trails for exquisitely sharp images.

Setup is easy and fast - the Polarie can be attached to a standard camera tripod and accepts a digital camera weighing up to 3.2 kilograms (seven pounds). An included compass on the Polarie Star Tracker mount makes a northern-direction alignment easy, along with a polar scope for alignment.

Courtesy of:

opticron

Vixen®

Five of our runner-ups will each receive a copy of ***Philip's Month-By-Month Stargazing 2016***

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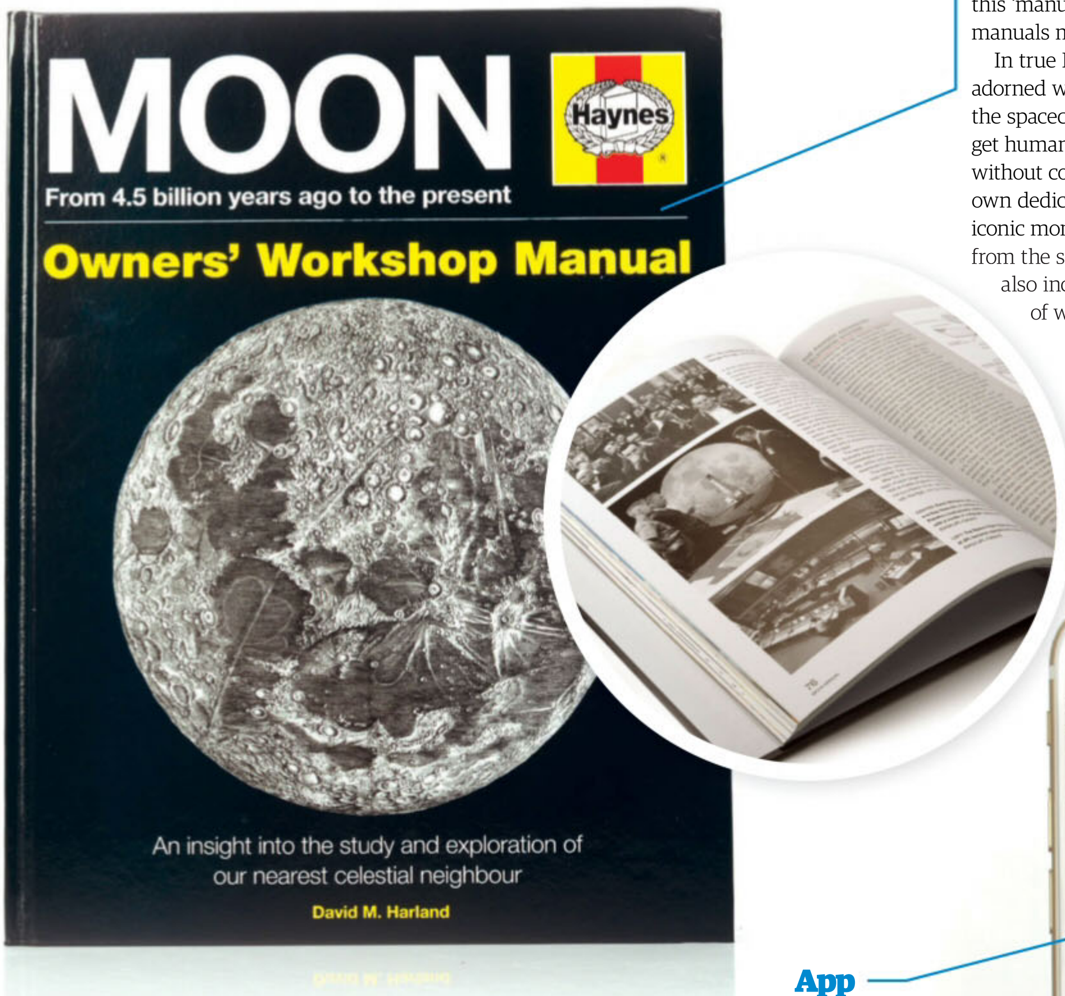
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Haynes
From 4.5 billion years ago to the present
Owners' Workshop Manual
An insight into the study and exploration of our nearest celestial neighbour
David M. Harland

Book

Haynes Moon Owners' Workshop Manual

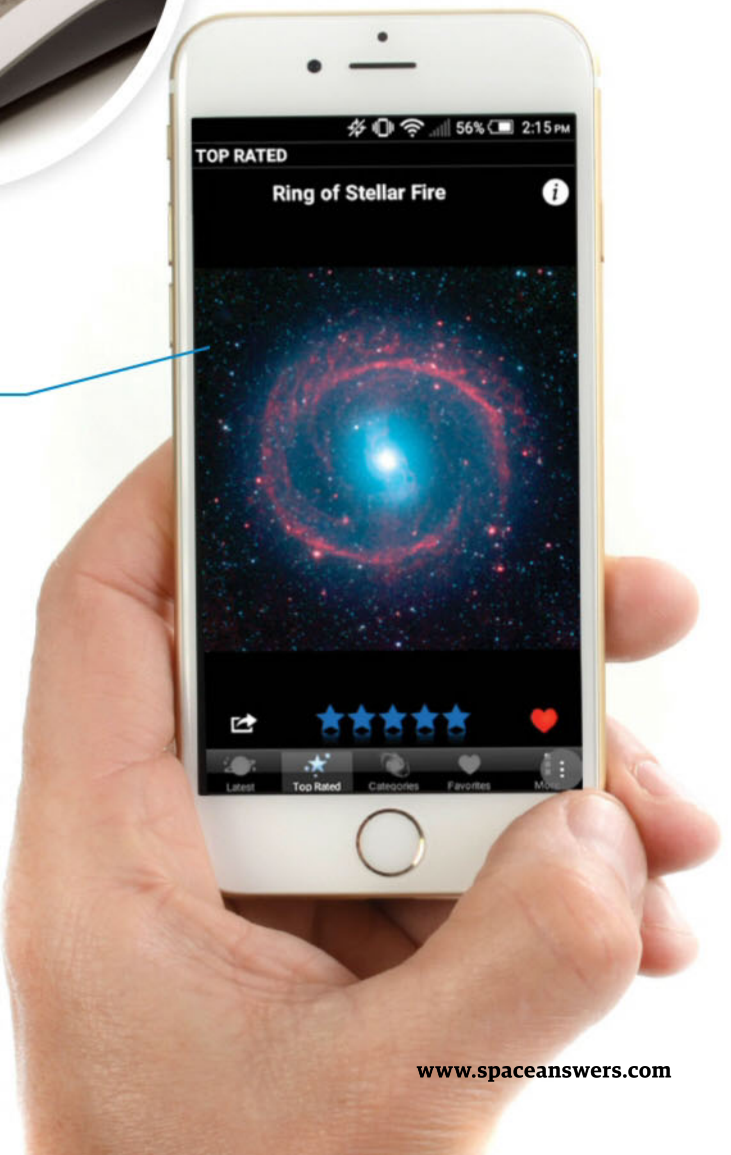
Cost: £22.99 (approx. $33.20)

From: Haynes Publishing

If you're passionate about the exploration of the Moon's past, present and future, we're confident you'll enjoy *Haynes Moon Owners' Workshop Manual*. Featuring up-to-date information on the rovers and orbiters that are currently on the lunar surface, this 'manual' is a very clever spin-off from the practical vehicle manuals made by the same publisher.

In true Haynes Manual style, this hardback book is adorned with photographs and annotated line drawings of the spacecraft designed to observe, take measurements and get humans to the Moon. The book wouldn't be complete without covering the Apollo Moon landings, which have their own dedicated sections, accompanied by photographs of these iconic moments in history. What we've learned about the Moon from the several missions that we have sent to its surface is also included in the text, providing an up-to-date overview of what we know about our natural satellite.

The *Haynes Moon Owners' Workshop Manual* is perhaps too light on text, but this does serve to make the book a lot more digestible to read and one that's ideal for the coffee table. An engaging narrative made it difficult to put down and enabled it to match up to the excellent standard of Haynes Manuals in general.



App

Space Images

Cost: Free

From: iTunes & Google Play

Fans of the breathtaking images found on NASA's website, and brought to us by the agency's fleet of space telescopes, will love Space Images, which has been devised by staff at NASA's Jet Propulsion Laboratory. The app works with NASA's website, which carries the same name, to enable you to discover the latest images and videos of our stunning universe – from stars to galaxies and nebulae to supernovae, Space Images keeps you up to date, on the go. To ensure that no one misses out, Space Images is downloadable to Apple and Android devices and is available on iTunes and Google Play. Downloading the app to an iPhone 6 is quick and easy and Space Images runs smoothly overall. As well as imagery, the app features videos, which sadly don't stream very well without a strong internet connection, and we did experience a great degree of stuttering and slow loading. However, given that the app is free, we certainly can't grumble too much! Space Images provides the option to rate space images and save an image of your choice to your device's background – an option that we loved and we're sure you will too!

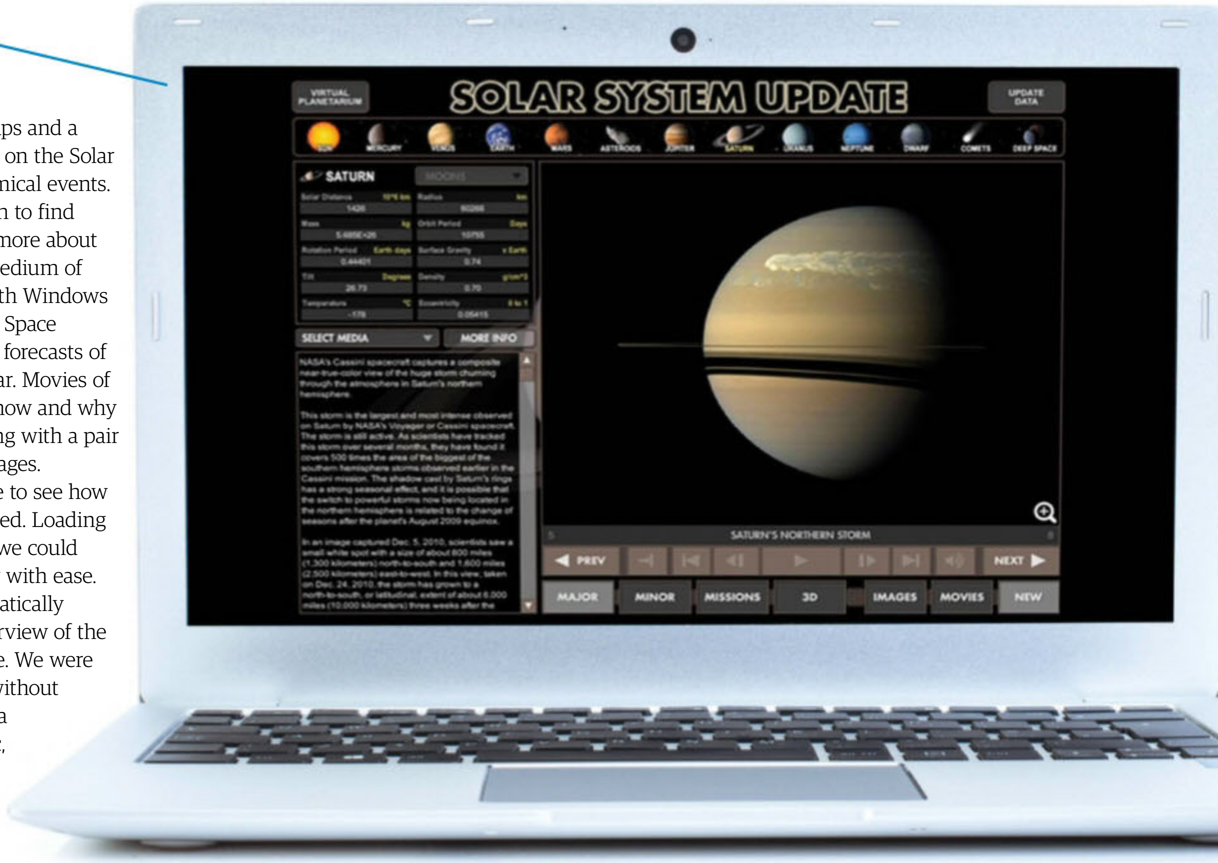
Software

Virtual Planetarium

Cost: $39.95 (approx. £26)
From: Name A Star Live

Virtual Planetarium includes interactive sky maps and a large library of imagery, along with information on the Solar System and details on the most recent astronomical events. It is ideal for budding astronomers who are keen to find their way around the night sky while learning more about our solar neighbourhood – often through the medium of movies. You can run Virtual Planetarium on both Windows and Mac OS X systems. We enjoyed the unique Space Weather programme that allows you to explore forecasts of the aurorae and solar flares from our nearest star. Movies of the Aurora Borealis and animations that show how and why this phenomenon occurs are also included, along with a pair of 3D glasses to view the three-dimensional images.

We took advantage of a clear evening in June to see how the integrated 'Sky Tonight' star charts performed. Loading the star maps, which have a very basic design, we could use them to find constellations in the night sky with ease. After hitting 'Play', the sky chart scrolled automatically across the map on our screen to give us an overview of the night sky and its observable objects at that time. We were also able to find planets and deep-sky objects without too much trouble, which we followed up using a telescope. Given that its graphics are quite basic, the software takes up a surprisingly large amount of storage on both Windows and Macintosh machines. Nevertheless, Virtual Planetarium is an adequate guide for the budding astronomer.



SATURN

Solar Distance 10^6 km: 1426
Radius km: 60268
Mass kg: 5.685E+26
Orbit Period Days: 10755
Rotation Period Earth days: 0.44401
Surface Gravity x Earth: 0.74
Tilt Degrees: 26.73
Density g/cm^3: 0.70
Temperature °C: -178
Eccentricity 0 to 1: 0.05415

NASA's Cassini spacecraft captures a composite near-true-color view of the huge storm churning through the atmosphere in Saturn's northern hemisphere.

This storm is the largest and most intense observed on Saturn by NASA's Voyager or Cassini spacecraft. The storm is still active. As scientists have tracked this storm over several months, they have found it covers 500 times the area of the biggest of the southern hemisphere storms observed earlier in the Cassini mission. The shadow cast by Saturn's rings has a strong seasonal effect, and it is possible that the switch to powerful storms now being located in the northern hemisphere is related to the change of seasons after the planet's August 2009 equinox.

In an image captured Dec. 5, 2010, scientists saw a small white spot with a size of about 800 miles (1,300 kilometers) north-to-south and 1,600 miles (2,500 kilometers) east-to-west. In this view, taken on Dec. 24, 2010, the storm has grown to a north-to-south, or latitudinal, extent of about 6,000 miles (10,000 kilometers) three weeks after the

SATURN'S NORTHERN STORM

Planetarium

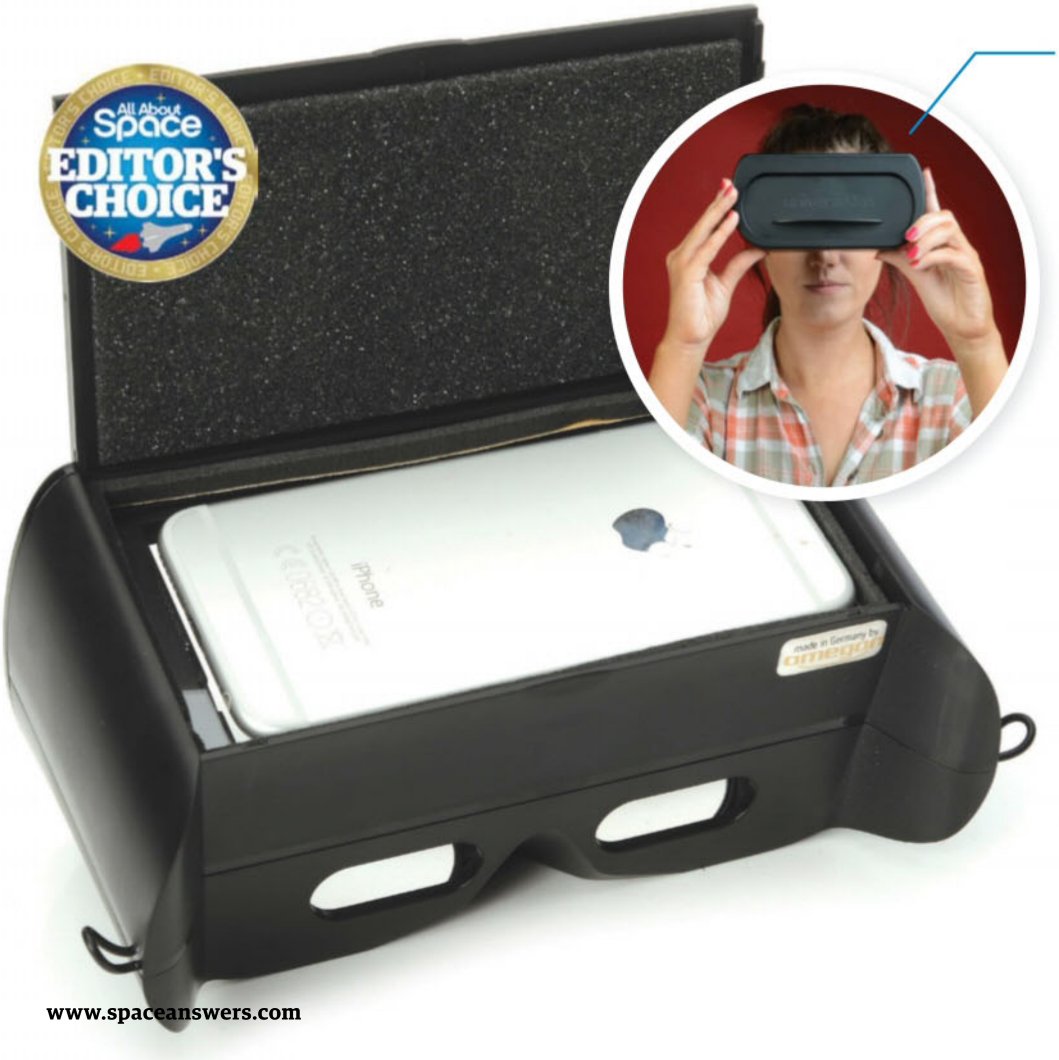
Universe2go

Cost: £79.00 / $99.00
From: universe2go.com

With an appearance akin to that of a virtual reality headset, Universe2go features a compartment where you're able to slot your Android or iPhone, which should be preloaded with the Universe2go app. Using your phone's gyroscope and GPS, the headset 'knows' which direction of the sky you're looking at in real time. The app also has the capability of placing a target in your field of view, which guides you in aiming your sights on specific night-sky objects, and locking on a target provides a small pop-up window that provides fast facts on the object. Locking on to constellations and objects for a few seconds will also kick-start audio explanations on what you're observing – ideal features that make learning and navigating your way around the night sky a breeze.

Universe2go offers different viewing modes that encompass observing for beginners and experts, and it also explores the mythology behind the names of the constellations, planets and deep space objects. Of course, you can use the app without the headset, but this defeats the object of having a hands-free observing experience. We enjoyed the ability to simply use head movements to flick through the app menu, but found that it took quite a bit of getting used to before we could comfortably switch it in and out of modes.

The setup of Universe2go is relatively straightforward yet effective all the same. Usable even when it's cloudy outside or if you're indoors, Universe2go is a fantastic spin on regular astronomy apps – we envision many manufacturers catching onto this genius invention in the future.



Stephanie Wilson

The second African American woman to go to space flew her first mission ten years ago

Stephanie Wilson is one of just three African American women to have travelled into space

Being an astronaut is no walk in the park. It is not a career that you can merely dip a toe into. It requires an intelligent scientific or engineering mind, a huge dollop of curiosity and many years of commitment and training to even be considered for a mission. But for Stephanie Wilson, the hardest part of her training was going in at the deep end: "I couldn't swim," she later revealed.

But thankfully she didn't sink. Wilson was selected by NASA as an astronaut candidate in 1996, four years after she had begun working at the Jet Propulsion Laboratory in Pasadena, California. With a degree in engineering science from Harvard and a master's in aerospace engineering from the University of Texas, she had certainly developed the know-how needed for her career to take off in the most literal sense.

For a number of years, she worked as a mission specialist and as a prime communicator with crews onboard the International Space Station (ISS). But then her time came in 2006 when she was selected for the Space Shuttle mission STS-121, which launched on 4 July. As well as being tasked with testing new safety and repair techniques that had been worked on in the wake of the Columbia disaster of 2003, the crew was also looking to deliver supplies.

Wilson was Mission Specialist 3 in a crew commanded by Steven Lindsey and piloted by Mark Kelly, and she was responsible for transferring over 6,800 kilograms (15,000 pounds) of equipment to the ISS. She also supported robotic arm operations for three purposes: vehicle inspection, extravehicular activities (EVAs) and the installation of the multipurpose logistics module.

After 12 days, 18 hours, 27 minutes and 54 seconds, she and her crew set off on the return journey to Earth. In the meantime, Wilson had become only the second African American women to go into space after Mae Jemison, 'beating' Joan Higginbotham, who was on board STS-116, by a matter of months.

It wasn't to be Wilson's last trip skywards, though. The following year, she was sent on another mission - STS-120 - this time as Mission Specialist 2. The crew sought to deliver the Harmony module, the utility hub that provided power and allowed for an extra 70 cubic metres (2,470 cubic feet) of living space, in order to make life more comfortable for the inhabitants of the space station. Also allowing for the possibility of connecting future international laboratories to the ISS, it was seen as vitally important.

During this mission, there was a problem that required four unplanned spacewalks. The array panels had snagged and become damaged, so to assist their repair, Wilson was again in control of robotic arm operations for EVA support and for the vehicle inspection. She also assisted the commander and pilot with space shuttle systems. But still Wilson wasn't done with space.

Having orbited the Earth 238 times on STS-120, she was sent back into space for mission STS-131 on April 5 2010. This was a re-supply mission, carrying 12,250 kilograms (27,000 pounds) of hardware, supplies, experiments and equipment to the ISS. Wilson was the primary robotic arm operator, directing the Leonardo module in and out of the shuttle's cargo bay.

Wilson is a highly regarded astronaut at NASA. In 2009 and 2011 she was given Distinguished Service medals, and in 2015 she also received Harvard's Distinguished Alumnus Award. She feels strongly about encouraging more women to seek careers in space, admitting that it's hard for young girls to see strong female roles in STEM (science, technology, engineering and math) on a regular basis, while pointing out the many opportunities that await those who seek space-based careers.

All About Space

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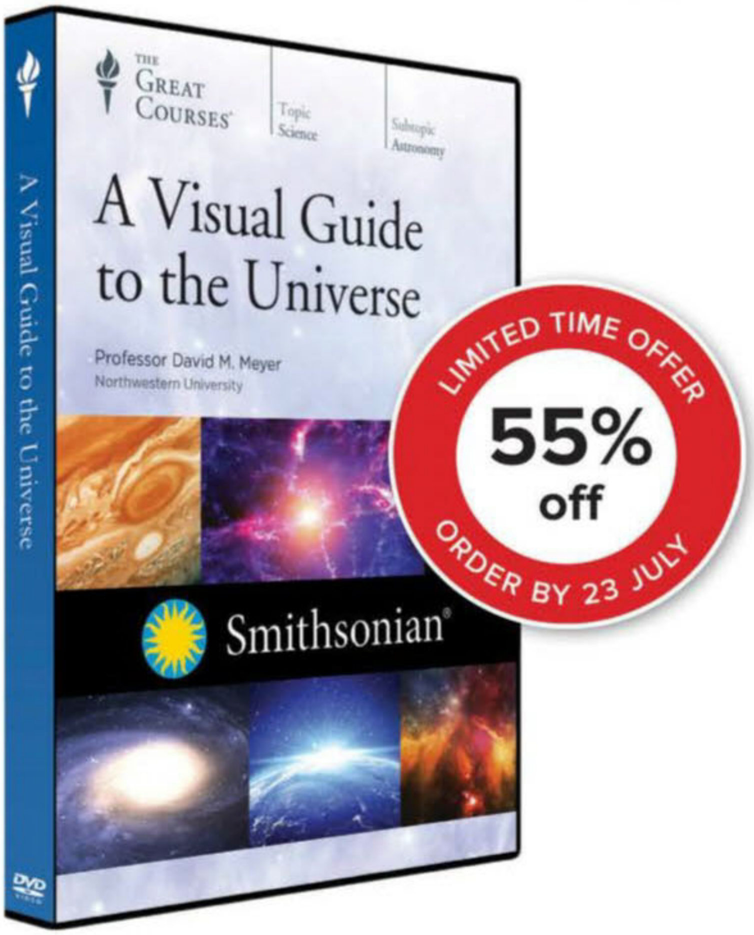

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